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A SYSTEM FOR SAMPLING, LABELING, AND
DIGITAL RECORDING OF OPTICAL MEASURE-
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Mark R. Weiss

Federal Scientific Corporation

Prepared for:

Rome Air Development Center
Advanced Research Projects Agency

April 1973

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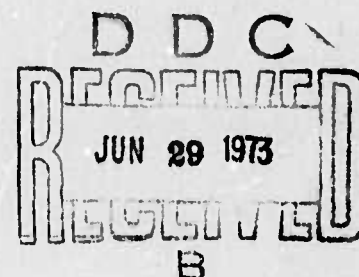
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Final Technical Report
April 1973



A SYSTEM FOR SAMPLING, LABELING, AND DIGITAL
RECORDING OF OPTICAL MEASUREMENT DATA

Federal Scientific Corporation



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RECORDING OF OPTICAL MEASUREMENT DATA**

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FOREWORD

This Final Report describes efforts by Federal Scientific Corporation, 615 West 131st Street, New York, NY, under contract F30602-71-C-0007, Job Order Number 12790208, for Rome Air Development Center, Griffiss Air Force Base, New York. This effort was partially sponsored by the Defense Advanced Research Projects Agency under ARPA Order Number 1279.

Mr. Donald O. Tarazano (OCSE) was the RADC Project Engineer.

This report has been reviewed by the RADC Information Office (OI) and is releasable to the National Technical Information Service.

This technical report has been reviewed and is approved.

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ABSTRACT

Optical measurement data generated at the Verona test site of RADC must be reduced in a computer to extract the desired parameters. These parameters are: angle-of-arrival, phase-structure function, modulation transfer function, and amplitude scintillation. This report describes a system which processes the raw measurement data and generates digital tape recordings suitable for input to a GE 645 Computer.

The system consists of two components. First, an Optical Data Processor (ODP) which reduces the dynamic range required for sampling and recording the raw data, and the storage volume required for the recordings. The ODP operates by performing the initial processing that is required for extracting the optical parameters. For the angle-of-arrival and phase-structure function this consists of measuring the phase angle. For the modulation transfer function, the envelope is extracted. Scintillation data are compressed logarithmically. Suitable automatic gain control, filtering, and shaping circuits are included to maximize the accuracy of the ODP outputs. Two ODP units were constructed, one for a visible light laser and the other for an infrared light laser.

The second component of the system is software which was written for the PDP-8 computer at the test site. These programs control the sampling and recording of the processed data and provide appropriate labels for each data record and data file. The programs also provide the ability to automatically search for the start of a desired data set and to sample and record the data for a specified interval. Two sets of programs were provided, one for the angle-of-arrival, phase-structure function, and amplitude scintillation data, and the other for the modulation transfer function data.

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1.0 INTRODUCTION

The work described in this report was carried out under Air Force Contract F30602-71-C-0007, in support of laser propagation experiments being conducted by Rome Air Development Center. An immediate objective of these experiments is to measure several of the effects of a non-uniform atmosphere on the transmission of laser light.

The role of Federal Scientific Corporation was to provide RADC with a system for recording the desired optical measurement signals onto digital magnetic tape for analysis by a computer.

The system being used by RADC to obtain optical data includes a telescope to collect the laser light, a rotating reticle with a different scanning pattern for each optical function to be measured, and optical/electrical transducers to convert the optical measurements to electrical signals. The system for recording the data consists of a PDP-8 computer which includes a 16-channel analog signal multiplexer, an analog-to-digital converter, and a digital tapewriter. An instrumentation tape recorder is available for recording optical data signals in analog form.

The technical objectives of the contract called for the digital recording of four kinds of optical measurement data: angle-of-arrival, phase-structure function, modulation transfer function, and amplitude scintillation. The signals which convey angle-of-arrival data consist, ideally, of a pair of constant frequency square-waves with variable relative phase angle. The desired information is contained in the phase angle. Phase-structure function is represented by a similar set of square waves. A single square-wave of varying frequency and amplitude conveys the modulation-transfer-function. Here, the envelope of the signal contains the

information. Finally, amplitude scintillation is represented directly by a noise-like AC signal which is centered about some DC level.

The data signals may be obtained live from the optical system, or they may be reproduced from analog tape recordings made on the instrumentation tape-recorder. In either case, it is necessary to preprocess them before they can be sampled, converted to digital form, and recorded onto magnetic tape in computer compatible format.

The live signals possess a far wider amplitude and frequency range than can be recorded onto analog tape by the instrumentation recorder, or than can be sampled, converted, and recorded onto digital tape. For example, at a reticle rotation speed of 300 rpm, the frequency of the phase-structure function square wave is 32 kHz. However, the upper bandwidth of the instrumentation recorder is 20 kHz when recording in the FM mode (as is required for accurate preservation of the signal waveform). At this same speed, the MTF bandwidth is likely to exceed 20 kHz (assuming a spot size of about 80 microns for visible laser light). Obviously, at the highest reticle speed, 1800 rpm, the problem of recording the optical data signals becomes six times worse.

Similar difficulties would occur if the data signals were to be sampled and recorded live. By the Nyquist criterion, the signals must be sampled at twice the frequency of the highest frequency component. The fastest that the PDP-8 computer at the test site can sample signals, store the samples in a data buffer, and periodically unload the buffer onto magnetic tape is about 10 kHz. Consequently, it is not possible to record, either in analog or digital mode, the live data signals for two of the three reticle speeds.

To get around this problem it is necessary to process the signals before sampling or recording them. The ideal in the preprocessing of information-bearing signals is to extract from them the essential information, leaving behind the carrier and other incidental components. Failing this, the next best preprocessor is one which transforms the signals so as to compress the amplitude and/or frequency range without at the same time losing or altering the essential information. For example, a highly accurate logarithmic compressor can be used to reduce the amplitude dynamic range which is required to record a signal.

The preprocessor which was developed under this contract uses both data extraction and signal transformation techniques. For the angle-of-arrival and phase structure function, the information contained in the relative phase-angles of the square-waves is extracted by high-speed phase meters. For scintillation, the wide amplitude-dynamic range is compressed by use of a linear-to-logarithmic converter. The information in the MTF is conveyed by the envelope of the variable frequency square-wave. This parameter is processed by peak detecting the signal, and passing the detector output through a 3.5-kHz wide filter. As a result, the original signal waveform is preserved at low frequencies and replaced by an increasingly smooth envelope at higher frequencies.

In addition to processing the data signals as described, the preprocessor generates signals which can be used to calibrate the outputs of the phasemeters. It also provides automatic gain control of the input signal to reduce the effects of signal amplitude fluctuation (scintillation) on the accuracy of the phase meters and the MTF system.

Two preprocessor systems were constructed under this contract: one for use with a visible-light laser and the other for an infrared laser. They are discussed and described in detail in Section 2.

The processed data signals, whether obtained live or from analog tape recordings, are sampled, the samples converted to binary numbers, and these written onto magnetic tape in computer compatible format. The sampling, digital conversion, and recording of the data is performed by the PDP-8 system under control of assembly language programs written under this contract. In addition to these operations, the programs also provide sufficient information with each data record and each file of records to identify the data and the conditions of the test, and to simplify the later computer analysis of the data. Finally, the programs include options which permit the user to select the start and stop times for the sampling and recording of data.

Two programs were provided. One of these is used for the angle-of-arrival, phase-structure function, and scintillation data. The other program is for sampling and recording the MTF data. These are discussed in Section 3 and described in Sections 4 and 5.

In addition to the programs cited above, several programs were developed for sampling, recording, and labeling meteorological measurements such as temperature, wind velocity, etc. In these routines, the number of parameters to be sampled and the sampling rate are set by the user, via the teletypewriter, at the start of a run. If desired, these programs can be used to sample and record the scintillation data simply by setting the sampling rate to 6000 Hz, to insure capturing scintillation components up to 2000 Hz. (To avoid any possibility of spectrum fold-over effects, it is recommended

that data which are sampled in this manner be low-pass filtered, with the filter breakpoint set at about one-third the sampling rate.)

2.0 THE OPTICAL DATA PREPROCESSOR

2.1 Design Concepts

The Optical Data Preprocessor (ODP), shown in Figure 1, receives the data signals which are generated by the telescope optical system and its associated electronics package. It processes them and provides as outputs versions of these signals which have been made compatible with the data handling capabilities of the analog and digital recording systems at the Verona test site. Two ODP's are provided, one for the infrared laser measurements and the other for the visible light data. Each ODP consists of three main systems: a pair of phasemeters for angle-of-arrival and phase-structure-function measurements, a peak detector for the MTF signal, and a logarithmic compressor for the amplitude scintillation signal. Also included are systems for calibrating the phase-angle measurements and for reducing the effects of amplitude fluctuations on the phase-angle and MTF measurements. In addition, timing signals are provided which mark the completion of each successive phase-angle measurement. These can be used to synchronize the sampling of the phase-angle data by the computer. Finally, a pulse train with a prf of one pulse per second is generated for use in timing the computer's sampling and recording of the preprocessor outputs.

The various circuits are fabricated on three 14 x 14 inch boards which are mounted horizontally in a 5-inch high frame. The three connectors into which the boards slide are wired in parallel, permitting the boards to be stacked in any sequence. A fourth connector, facing upward, is provided to facilitate servicing of the boards, as shown in Figure 2. As described in Section 2.3, suitable controls and indicators are provided on the front panel for the selection and monitoring of the various functions provided by

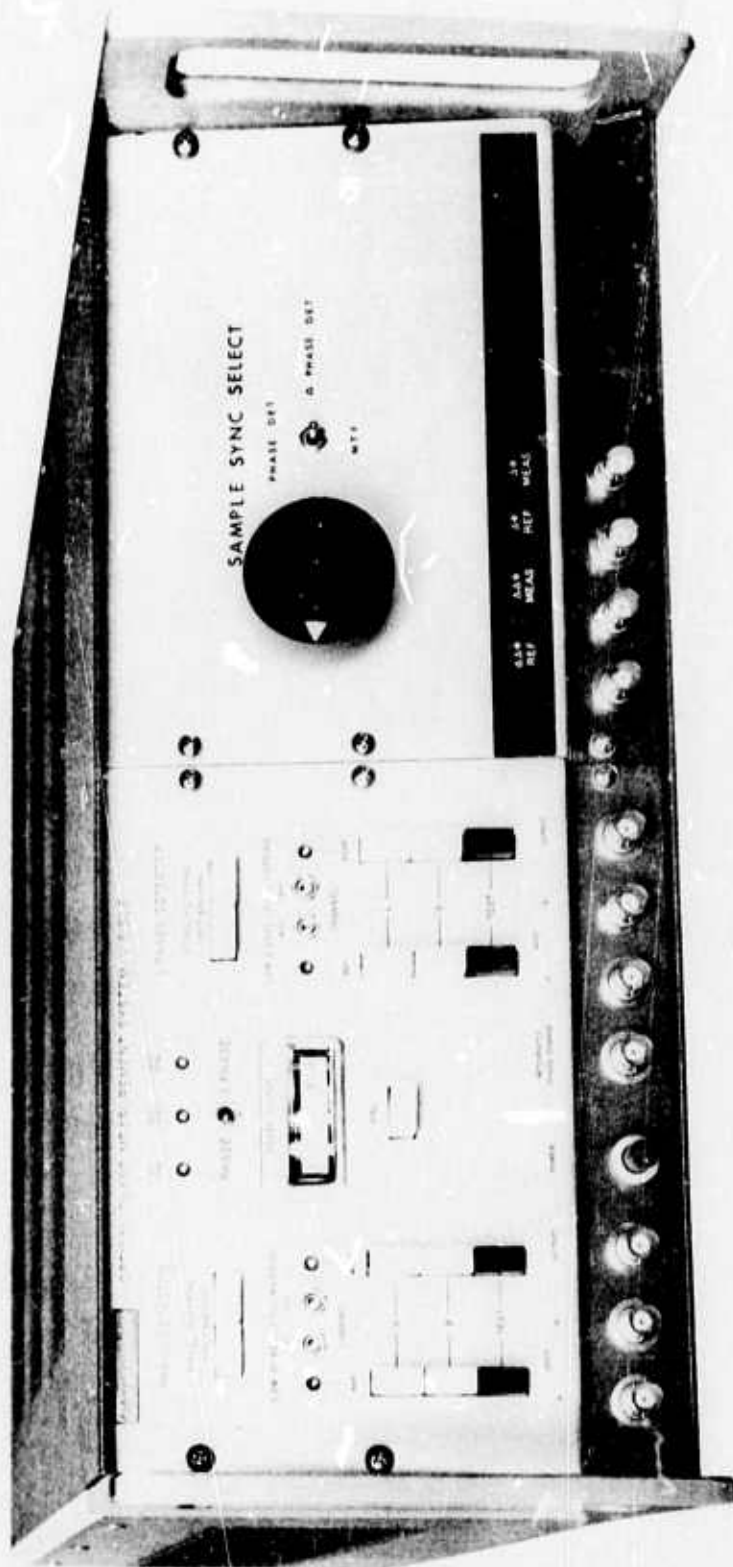


FIG. 1 THE OPTICAL DATA PROCESSOR, VISIBLE LIGHT SYSTEM

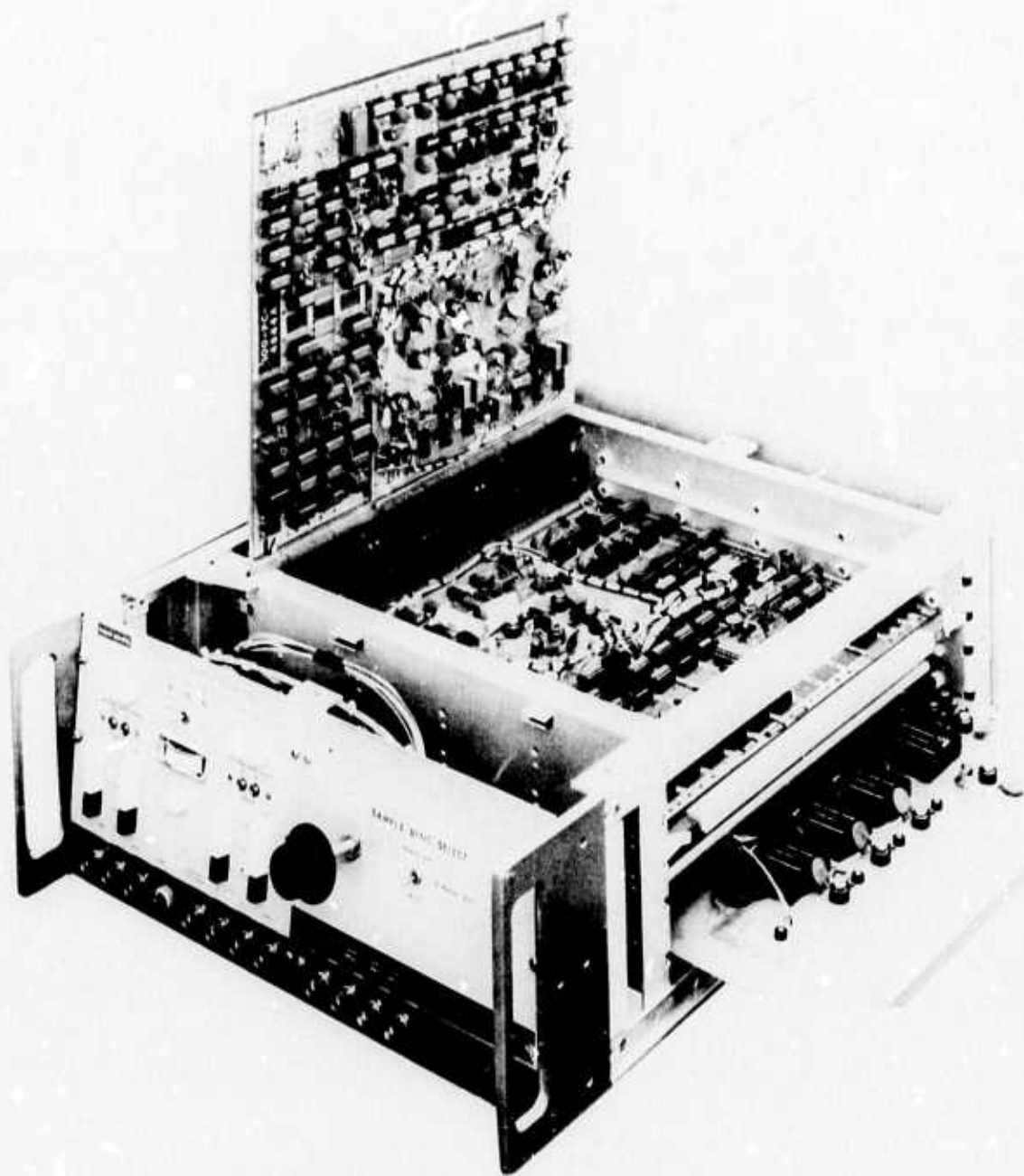


FIG. 2 ARRANGEMENT OF CIRCUIT BOARDS
FOR SERVICING THE ODP

the ODP. Power for the unit is provided via a cable from a remotely located power supply.

2.1.1 The Phasemeters

The input to either the phase-structure function ($\Delta\phi$) or angle-of-arrival ($\Delta\Delta\phi$) phasemeter consists of two signals, one a reference and the other the data. For both functions the reference signal is obtained from a point-light source, within the telescope, that is chopped by a uniformly spaced grating or pattern on a rotating reticle. A different grating is used for each function. For the $\Delta\Delta\phi$ function, the data signal is obtained by passing the received laser light through the appropriate pattern on the reticle. For the $\Delta\phi$ data, the light that is chopped by the reticle grating is not the received light itself, but a spatial interference pattern derived from it.

Ideally, these signals should appear as constant amplitude, constant frequency square waves, with only the relative phase angle between the data signals and the reference changing. In practice, the signals are constant in frequency, but their shapes deviate greatly from the ideal. The references are constant in average amplitude, but exhibit a slightly rounded top and bottom, and clearly rounded sides. Due to the limited intensity of the reference light source, these signals are accompanied by a small, but not negligible amount of noise that is generated by the photomultiplier. The data signals show significant variations in amplitude, are much more rounded, and exhibit a signal-to-noise ratio that ranges from about 15dB to about 6dB.

To improve the quality of the input signals before attempting to use them in phase angle measurements, the phase meters are preceded by an input section which consists of AGC circuitry, and filtering and shaping circuitry.

These are described in Sections 2.1.1 and 2.1.2 below. The phasemeters themselves are described in Sections 2.1.3, 2.1.4, and 2.1.5.

2.1.1.1 The AGC Circuits

The function of the AGC circuits is to reduce those variations in the amplitudes of the data signals which are due to variations in the intensity of the received laser light. Since these variations are represented by the AC component of the scintillation signal, the AGC circuits are designed to extract and use this component.

A block diagram of the AGC system is shown in Figure 3. The scintillation signal which is generated during infrared measurements is chopped in the optical system before being converted to an electrical waveform. Consequently, the first operation in the AGC system of the Infrared ODF is to detect both the positive and negative peaks of the scintillation signal and sum and store them in a sample-and-hold circuit. The input to the negative peak detector is inverted before detection so that the two peak values can be added constructively. The summed peaks are then sampled and applied to a variable gain amplifier (actually a multiplier/divider module) whose output is the desired AGC signal.

The sampling control signal is obtained from the optical system. It is amplified and applied to a Schmitt Trigger-Mono system. This circuit first generates a sampling pulse to transfer the current AGC data to the output amplifier. It then generates a discharge pulse to remove the data from the sample-and-hold input to permit storage of the next detected peak amplitude.

For the visible laser experiments the scintillation signal which is provided by the optical system is not chopped. Therefore, none of the

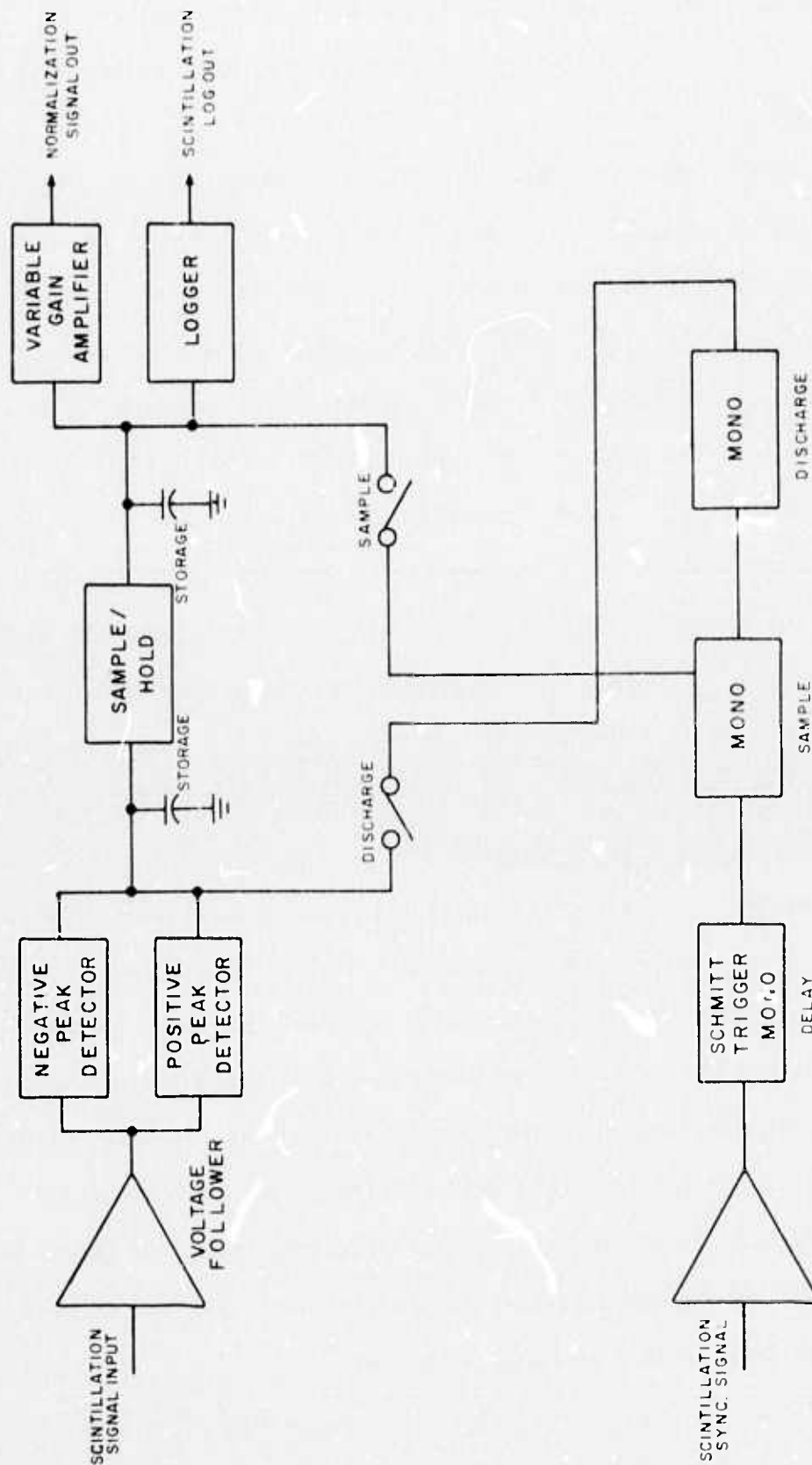


FIG. 3 BLOCK DIAGRAM - AUTOMATIC GAIN CONTROL CIRCUIT

sampling circuitry described above need be employed in the Visible ODP. Instead, the signal is simply rectified continuously and then applied directly to the output amplifier.

To reduce the amplitude variations in an incoming data signal, the detected scintillation signal is applied to the divisor input of an analog multiplier/divider module and the data signal is applied to the normal input. Since the amplitude of the data signals vary in proportion to the scintillation signal, a data signal can be regarded as a constant, K , multiplied by the scintillation signal. By taking the data signal $(K)(\text{Scint})$ and dividing it by (Scint) , the scintillation factor drops out and the signal amplitude becomes constant. Various trimmer adjustments are provided to insure that the constant numerical ratios are correct, so that there is neither gain nor loss in the system and everything tracks properly. When this condition is achieved, the AGC system will correct for amplitude changes over a 20dB range, within a scintillation bandwidth of 3kHz.

2.1.1.2 The Filtering and Shaping Circuits

The filtering and shaping circuits, illustrated in block diagram form in Figure 4, are designed to maximize the accuracy of the phase-angle measurements by reducing both the noise level and the rise and fall times of the input "squarewave" signals. After being corrected for amplitude variations due to scintillation, the input signals are applied to an IC voltage follower and thereafter to a two-pole active filter. The filter's center frequency is switched, in accordance with the rotational speed of the reticle, to correspond to the expected frequency of the input signal. A list of these frequencies is presented in Table 1, below.

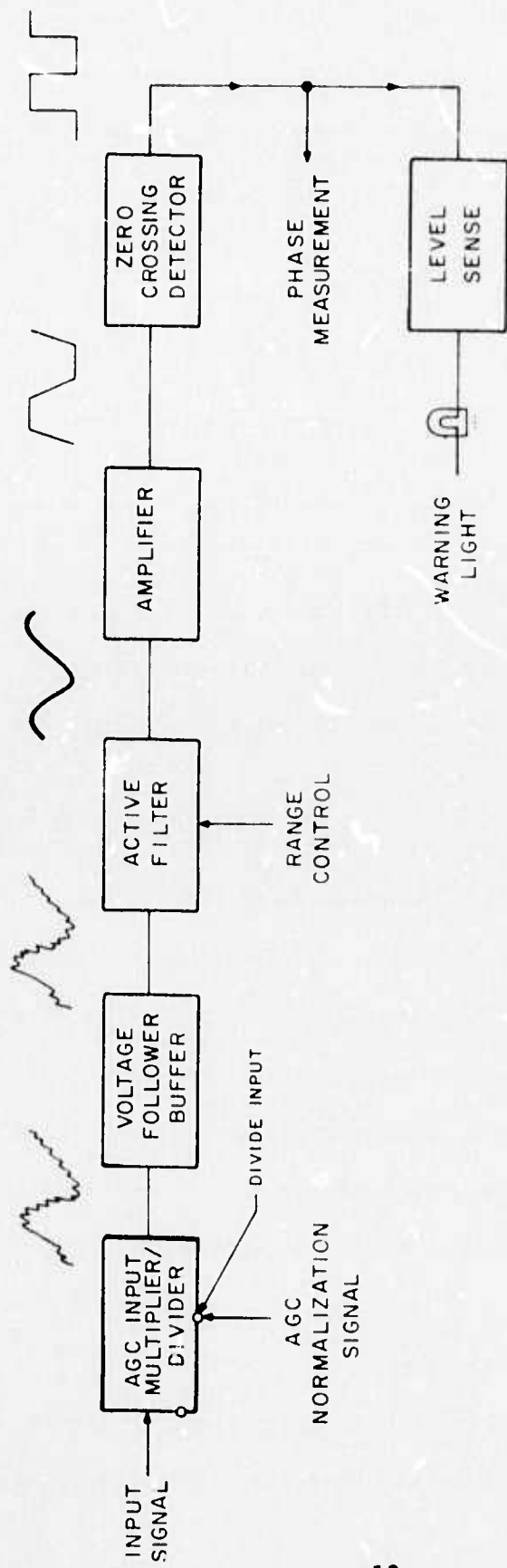


FIG. 4 BLOCK DIAGRAM-INPUT FILTERING AND SHAPING CIRCUIT

TABLE 1
SQUARE-WAVE INPUT SIGNAL FREQUENCIES

Signal	System	Reticle Speed (rpm)	Frequency kHz
$\Delta\phi$	Visible	1800	192
		300	37
		60	6.4
	Infrared	1800	28.2
		300	4.7
		60	0.04
$\Delta\Delta\phi$	Both	1800	0.96
		300	0.16
		60	0.032

The filter has a bandpass characteristic with a constant Q of about 10. This helps to remove much of the noise that accompanies the signal.

After passing through the filter, the signal is amplified and applied to a zero-crossing detector. The detector output, a square-wave of the same frequency as the input signal, but with much less noise and a minimum of phase jitter, is applied to the phase measurement circuitry.

The amplitude of the output square-wave is compared to the minimum level which will permit reliable phase-angle measurements to be made. Whenever the amplified and shaped square-wave fails to exceed this threshold, a level sensing circuit generates a signal which produces a special negative voltage at the phasemeter output. This signal also illuminates a light on the front panel to warn the operator that the measurement conditions are poor.

2.1.1.3 $\Delta\phi$ Phase Measurement Section

The $\Delta\phi$ phase measurement circuit, illustrated in Figure 5, operates by measuring the time difference between successive zero-crossings of the

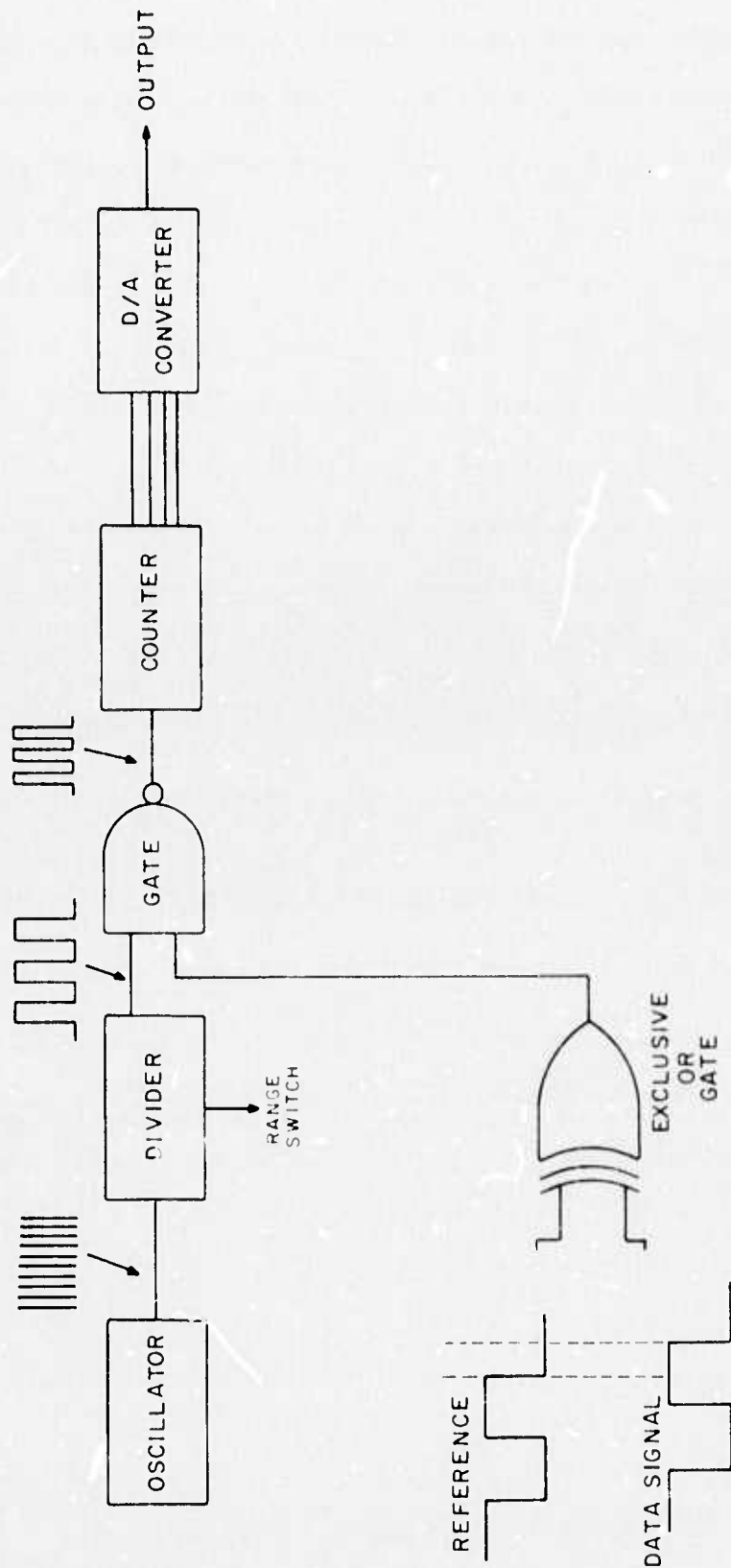


FIG. 5 BLOCK DIAGRAM - $\Delta\phi$ PHASE MEASUREMENT CIRCUIT

reference and measurement signals. A high-speed clock signal is generated and divided down to an appropriate frequency. A counter is started on one edge of the reference signal and stopped on the corresponding edge of the measurement signal. The number of clock cycles counted is thus proportional to the phase difference between the two signals. The frequency division of the high-speed clock is selected such that the frequency of the counted clock signal is proportional to the selected RPM range. By this means, the phase-measurement range is held constant at 360 degrees, even though the absolute time interval between the signal transitions varies according to the input frequency. Similarly, the minimum measurable phase difference will be independent of the reticle speed, as shown in Table 2. The digital number proportional to the measured phase difference is converted to analog form by a D/A converter and applied to the front panel output jack.

TABLE 2
RESOLUTION AND RANGE OF OPTICAL PHASE MEASUREMENT SYSTEMS
(In Degrees)

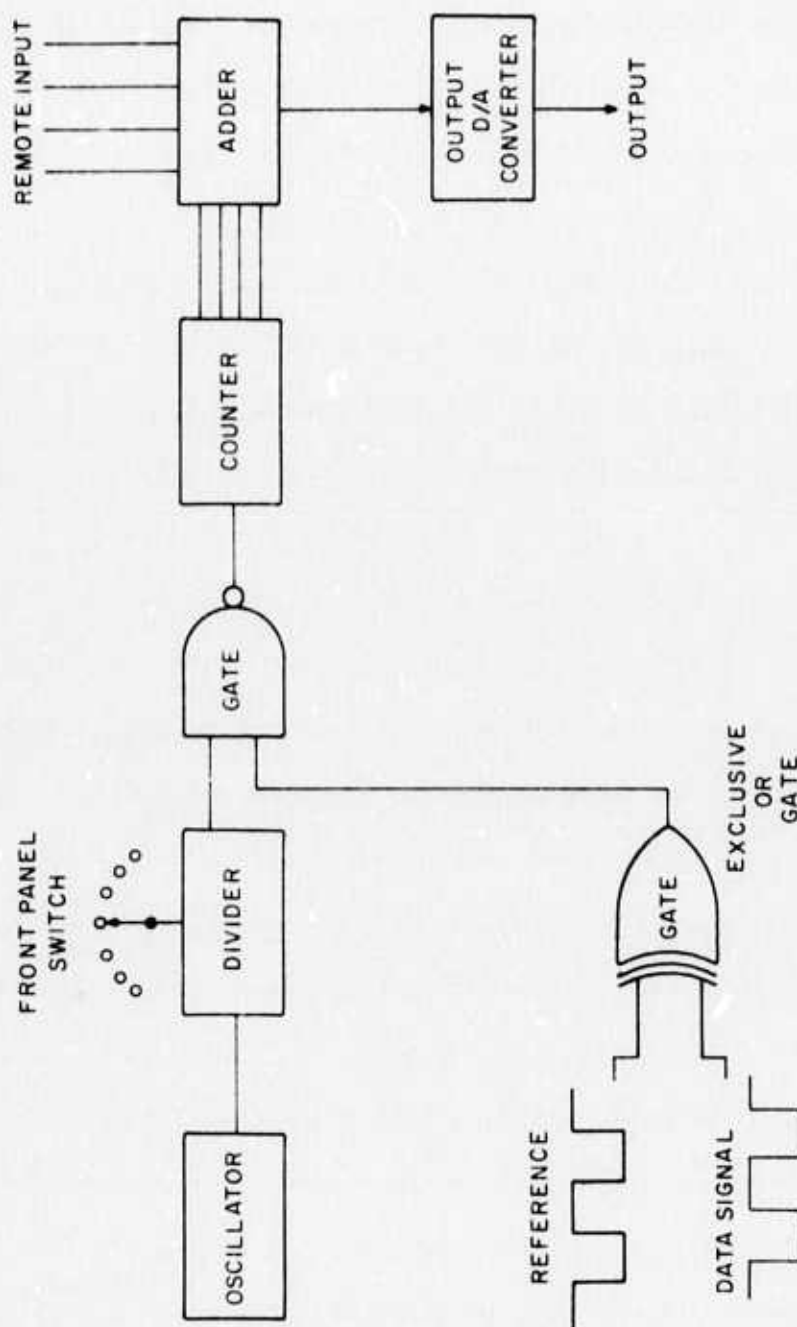
Reticle Speed (RPM)	$\Delta\phi$ Resolution		$\Delta\Delta\phi$	
	Visible	Infrared	Resolution	Range
60	6.55	0.97	0.136	136
300	6.55	0.97	0.0225	22.5
1800	6.55	0.97	0.0045	4.5

2.1.1.4 $\Delta\Delta\phi$ Phase Measurement Section

The operation of this circuit (illustrated in Figure 6) is similar to that of the $\Delta\phi$ phasemeter except that the divider is eliminated so that the same clock frequency can be counted on each range. Thus, the measurable phase-angle range varies with reticle speed, as does the resolution of the measurement (see Table 2 above). To permit the tradeoff between range and resolution to be varied, an additional clock-frequency divider was installed which is variable from the front panel and gives selectable resolution in factors of two. This circuit is independent of the RPM range to which the device is set. An adder is provided to enable the phase origin to be set remotely. The pin connections for the external phase-origin data are listed in Appendix 1.

2.1.1.5 Integrated-Phase-Change Measurement Circuitry

This circuit is employed to count the number of phase rotations between the two input signals in the $\Delta\phi$ phase measurement section. It does this by sensing when the phase changes from near plus 180 degrees to near minus 180 degrees, or vice versa. To perform this function, a counter similar to that in the phase-measurement section is employed, although it has less resolution. Each phase measurement produces a given analog output voltage which is applied to a differentiator, as shown in Figure 7. As each measurement is made, the change in phase is differentiated. The height of the resulting pulse will be proportional to the magnitude of the phase change. A small change produces a small pulse, while a full-scale change, corresponding to a rotation, produces a large pulse. The pulse is threshold detected to discard small changes, and polarity detected to determine the direction of rotation. The pulses are then applied to an up/down counter to keep track of how many pulses of each polarity have occurred. The output of

FIG. 6 BLOCK DIAGRAM - $\Delta\Delta\phi$ PHASE MEASUREMENT CIRCUIT

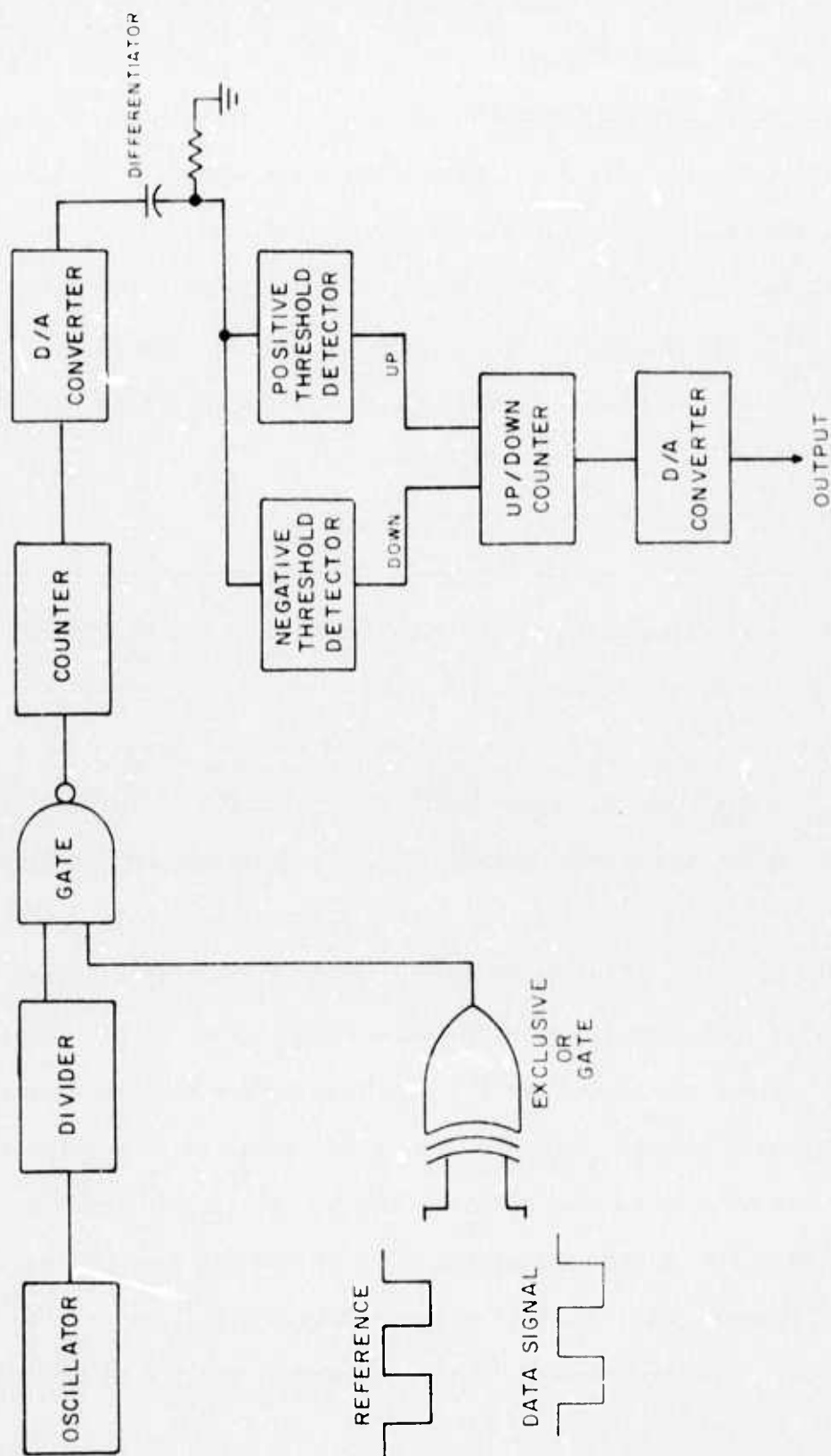


FIG 7 BLOCK DIAGRAM - INTEGRATED PHASE-CHANGE MEASUREMENT CIRCUIT

this up/down counter is applied to a D/A converter, whose output corresponds to the Integrated Phase Change.

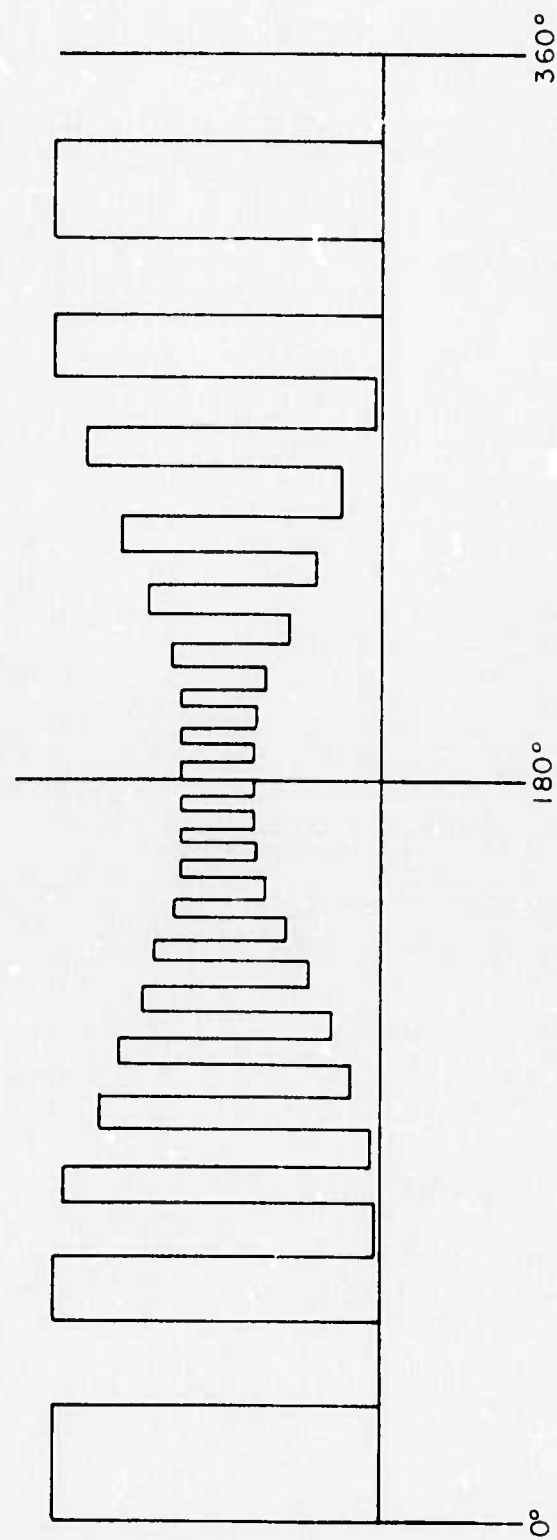
2.1.2 The Scintillation Circuit

In accordance with the requirements for maximizing the dynamic range for analysis of the scintillation data, the scint signal which is extracted by the AGC circuits is applied to a logarithmic compression module (see Fig. 3). The resulting signal easily can be recorded within the 40-dB dynamic range of the Ampex instrumentation recorder or within the 9-bit sampling range which is used by the PDP-8 programs.

2.1.3 The Modulation Transfer Function Circuit

The Modulation Transfer Function (MTF) is conveyed by the envelope of a square-wave signal such as is illustrated in Figure 8. The MTF signal provided by the optical system is centered about some DC level. The maximum waveform amplitude occurs when all of the received light passes through a slit on the MTF track of the scanning reticle, the minimum when all of it is blocked by the space between two slits. The minimum peak-to-peak variation occurs when about half of the light is blocked and half passes through.

The envelope is extracted by use of the circuit illustrated by the block diagram in Figure 9. After being amplified, the raw MTF signal is applied to an AGC multiplier/divider module to remove amplitude variations caused by scintillation. Following this, the signal is peak-detected and then smoothed by a short time-constant filter. The filter break-point is chosen to pass all of the information which is likely to be present in the envelope. However, since part of the square-wave signal is at frequencies which are below the break-point, the corresponding portion of the extracted



RETICAL ROTATION ANGLE
FIG 8 IDEALIZED MTF WAVEFORM

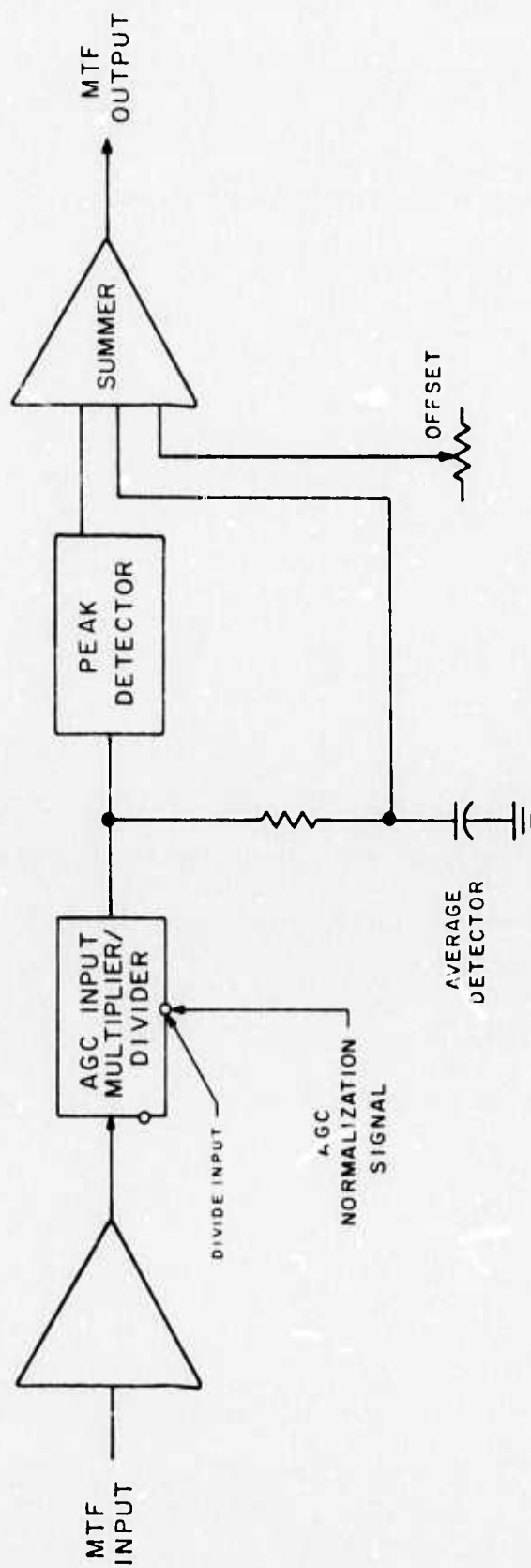


FIG. 9 BLOCK DIAGRAM - MTF CIRCUIT

MTF envelope exhibits a square-wave component. As described in Section 5, the program for sampling the MTF is designed to complete the extraction of the envelope.

An offset is provided at the input to the output summing amplifier so that the output level with no signal input is -1 volt, and with maximum input is +1 volt. An additional offset level is provided to zero-out any long-term variation in the DC or average DC level of the input signal.

2.2 ODP Input Signal Requirements

As the optical phase measurement system is just that - a phase measurement system, it should be relatively indifferent to the amplitude of the input signals. To achieve this independence, a fairly complex AGC (automatic gain control) system is employed which takes an independent sample of the signal amplitude and varies the system gain in a manner designed to present a constant level to the input signal processing circuitry. After filtering, the signal is clipped so that only the phase information is recovered.

In view of this, the signal levels given below are purely nominal, a variation of +20 dB may be expected in normal operation.

<u>SIGNAL NAME</u>	<u>NOMINAL LEVEL</u>
$\Delta\phi$ PHASE MEASUREMENT REFERENCE	0.1V RMS
$\Delta\phi$ PHASE MEASUREMENT DATA	0.1V RMS
$\Delta\Delta\phi$ PHASE MEASUREMENT REFERENCE	0.1V RMS
$\Delta\Delta\phi$ PHASE MEASUREMENT DATA	0.1V RMS
SCINTILLATION	Varies from 1 to 10V
MTF INPUT	0 to 5V (centered about 2.5V)
MTF SYNC	Greater than 1 volt

OTHER SYNC SIGNALS

TTL Logic Levels (low less than 0.8V; high greater than 2.1V).

REMOTE CONTROL SIGNALS

SWITCH CLOSURE TO +5V or Ground

REMOTE ORIGIN SET

TTL Levels

OUTPUT SIGNALS

EXPECTED CHARACTERISTICS

PHASE MEASUREMENT OUTPUT
($\Delta\phi$ or $\Delta\Delta\phi$)

+2V to -2V nominal, depending upon the input phase relationship

(Note that this signal will assume a voltage of about -5 if either the input data or reference signal is insufficient for a valid output. If this occurs, the associated low-signal warning light on the front panel of the ODP will be illuminated.)

INTEGRATED PHASE CHANGE OUTPUT

+5 to -5V, depending upon number and direction of phase rotations in $\Delta\phi$ Phase Measurement channel.

SCINT LOG OUT

$\pm 1V$, depending upon scintillation signal amplitude

MTF OUT

$\pm 1V$

COMPOSITE SYNC OUT

TTL LEVEL

INPUT SIGNAL VIEWING JACKS

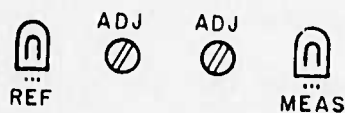
Approximately 0.1V square wave

2.3 Operation of the ODP Controls

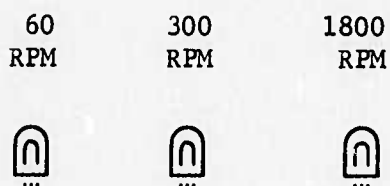
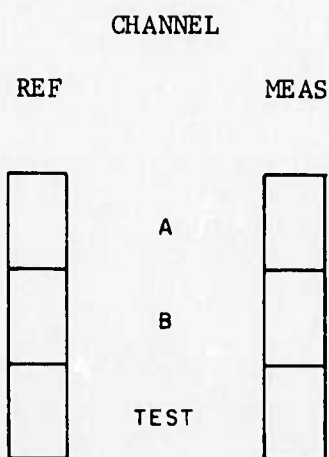
The discussion below applies equally to the Infrared and Visible ODP units, since the front panel configurations are nearly identical. It is assumed that the optical system is applying the appropriate signals to the various inputs. The controls or indicators that are sketched below correspond roughly in appearance and layout to their counterparts on the ODP unit. (See the photograph of the VISIBLE ODP, Fig. 1, for comparison.)

<u>CONTROL NAME</u>	<u>FUNCTION OR INDICATION</u>
(Phase detector control group: left side of panel for $\Delta\phi$ phase measurement, right side for $\Delta\Delta\phi$)	
<div style="display: flex; justify-content: space-between;"> <div style="text-align: center;"> <u>SIGNAL FILTERING</u> DIRECT BANDPASS <div style="border: 1px solid black; width: 100px; height: 20px; margin-top: 5px;"></div> </div> <div> Depressing the BANDPASS button routes the input signal through that input filter whose center frequency is equal to the expected value of the input frequency. Depressing the DIRECT button bypasses this filter. </div> </div>	

LOW SIGNAL LEVEL WARNING



This group is used to indicate that the level of the incoming signal is insufficient to properly activate the measurement circuitry. The left hand light-emitting diode becomes illuminated when the signal in the reference channel is too low, the right hand LED lights when the measurement signal is



too low. The two screwdriver-adjust potentiometers set the warning level for their associated LED indicators.

THIS group of switches routes the input signals to their appropriate channels. The left hand pushbutton group selects the input from either the "A" or the "B" input connector and routes it to the reference channel. The right switch group selects the input from either the "A" or "B" connector and routes it to the measurement channel. Note that it is possible to have the same signal going to the reference and the measurement input, thus giving a quick check on system stability and symmetry.

This group of indicators show to which rotation speed of the reticle the system is switched. There is no control function associated with them, since they are switched externally by the FSC supplied switch. They also can be switched by the optical system. A con-

nector is provided on the back of the ODP for this purpose. The appropriate connections are:

<u>Signal</u>	<u>PIN</u>
1800 rpm	AA
300 rpm	BB
60 rpm	CC
Common	DD

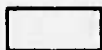
Δ PHASE  $\Delta\Delta$ PHASE

PHASE OUTPUT

METER

The toggle switch and meter are used to give a gross indication of system operation. The switch connects the meter to either the $\Delta\phi$ Phase Detector output, or to the $\Delta\Delta\phi$ Phase Detector output, and the meter indicates the DC voltage present at the selected output. For rapidly changing input signals, the indication is meaningless, as the meter will remain approxi-centered. However, a check of operation can be made by connecting a reference signal and a manually varied measurement signal to the input. The meter will then give a rough indication of the phase difference between the two applied signals.

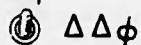
CAL



Depressing this momentary pushbutton applies a step-variable phase signal at the appropriate frequency to the system inputs, bypassing the front panel connectors. This signal is used for automatic calibration of the system before and after the ODP is used to process received optical data.

SAMPLE SYNC

$\Delta\phi$



MTF

This three-position toggle switch selects which of the three possible sample-sync-pulses is applied to the rear panel composite-sync output jack. Note that this switch is effective in the calibration mode. However, when in CAL, the output-sync pulses are inverted.

POWER



THIS pushbutton switch is used to apply power to the unit. Depressing it causes its internal lamp to become illuminated, thus indicating that power is indeed applied. Redepressing this control turns the lamp off and disconnects power.

LOCATION - LEFT HALF PANEL

INPUT

A



B



These BNC connectors are used to apply signals from the optical system to the measurement system. Measurement and Reference channels are interchangeable at this point. The selection of which channel is routed to the Reference input is made in the switch group immediately above the connectors. The left hand jacks are for the $\Delta\phi$ phase measurement signals, the right hand jacks are for the $\Delta\Delta\phi$ phase measurement signals.

OUTPUT



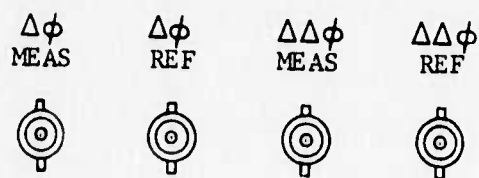
The jack immediately to the right of the two input jacks is the output jack for the same function.

INTEGRATED PHASE CHANGE



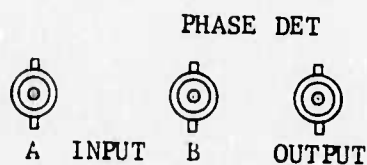
This BNC connector provides a DC signal whose level is proportional to the number of times the $\Delta\phi$ phase measurement signal has rotated 360 degrees with respect to its reference signal since the last calibration cycle.

LOCATION - RIGHT HALF PANEL



These BNC jacks are isolated viewing ports to enable the operator to determine if the processed signals are of adequate quality. The test point is located immediately after all analog processing (i.e., AGC, filtering, and shaping) has taken place. Thus the signals should appear to be square waves with no ragged edges.

LOCATION - REAR PANEL



In each case, the BNC jack in the left hand drawing is wired in parallel to the identically named jack on the front panel, and performs the same function. This is done as a convenience feature. For obvious reasons, one should not connect two different signals to the front and rear panel input connectors. If the signals are connected to the rear panel, it is permissible to view them from the front panel with an oscilloscope.

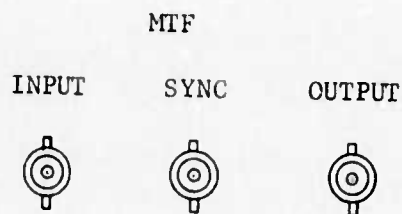
INTEGRATED PHASE CHANGE



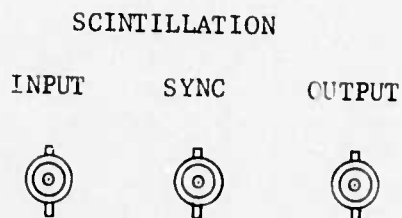
COMPOSITE SYNC OUT



This jack provides the sync as selected by the front panel switch (see page 28).



These three jacks are for the Modulation Transfer Function signals. The input jack accepts the raw signal, the output jack provides the processed output. The Sync signal is used as a reference and may be applied to the composite sync output jack by means of the front panel control. The presence or absence of this synchronizing signal does not affect the processor in any way.



The scintillation signal is used by the AGC system to adjust the amplitudes of the other input signals. It is applied to the Input jack (left). The Sync input is required only in the Infrared Measurement System, where it is used as a reference for sampling the scintillation signal. The Output jack provides a signal proportional to the Log of the Scintillation input signal, suitable for recording by the Ampex FR-100, or sampling by the PDP-8.

DC INPUT



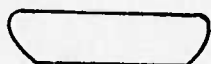
These three jacks are for connecting the power supply. The DC input jack receives the various DC voltages from the power supply unit.

AC OUTPUT



The AC input jack is plugged into a source of 115VAC 60Hz, and is switched by means of the power on/off switch to the AC Output jack, which supplies 115 VAC to the power supply unit.

AC INPUT



The power supply has two separate sections, one for each ODP unit. Thus each measurement unit can control its own section of the power supply.

Additional Connectors

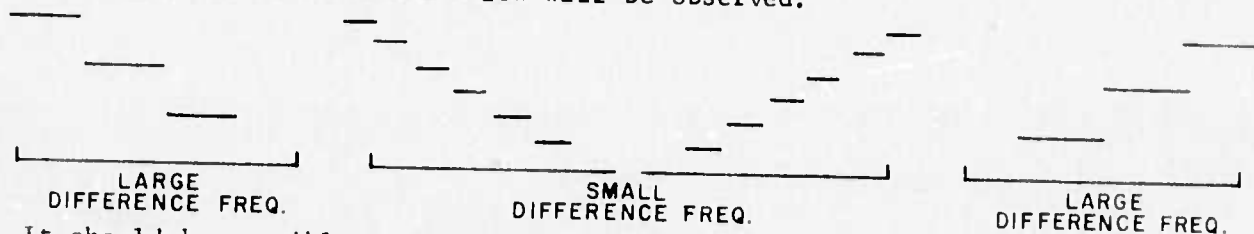
Additional connectors are provided to allow external range switching, and to enter an origin phase into the phasemeter.

2.4 Operation and System Checkout

This section describes a method which can be used to confirm that the phase measurement sections are operating correctly. The only equipment required is a pair of sine wave generators with variable frequency output between 32Hz and 192kHz, and with a reasonable short-term stability. Connect

one of the generators to the Phase Measurement A input and set its output frequency to $940\text{Hz} \pm 20\text{Hz}$ for the Infrared ODP or to $6.4\text{kHz} \pm 125\text{Hz}$ for the Visible ODP. Connect the other generator to the B input and set it for approximately the same frequency. Set the range switch (i.e., the reticle speed switch) to 60 rpm.

Using the input selector switches, route the first generator to both the measurement and the reference channels. Switch the meter to the left-hand position and notice that the pointer is approximately centered. Observe the phase measurement output on an oscilloscope and observe that the output voltage is approximately 0 volts. Now, route the second generator to the measurement channel and leave the reference channel connected to the first generator. Depending upon the frequency difference between the generators, waveforms similar to those below will be observed.



It should be possible to obtain any of these waveforms by slightly adjusting either of the generator frequencies. (At high frequencies, these adjustments are fairly delicate.) Check the Integrated Phase Change output by setting the generator difference frequency to give a fairly rapid waveform (approximately 10 steps). Observe the integrated phase change output and note that a similar waveform is present, whose period is 64 times that of the phase-change waveform. Set the generator difference frequency to give a phase change waveform of the opposite sense (rising if at first it was falling), and observe that the integrated phase change output reverses sense also, again with a period 64 times that of the phase change measurement.

Repeat the above experiment with both generators set to the frequencies shown in Table 1. It is necessary only to check the integrated phase change output at one frequency for each system.

After completing these tests and obtaining proper indications, remove both generator inputs from the measurement system. Observe that the warning lights come on and that the voltage at the output jacks drops to below -4 volts. Depress the CAL button and observe that the warning lamps extinguish and that a signal similar to that obtained when using the signal generators is present at all the output jacks.

This completes the functional checkout of the phase measurement system.

There is no convenient method of checking out operation of the MTF system. The MTF waveforms are sufficiently complex so that no simple check can determine proper operation. If difficulty with this circuitry is suspected, it will be necessary to use the schematics in conjunction with the theory of operation section to locate the fault.

The procedure for aligning the AGC system is as follows:

- 1) Apply a 50-percent amplitude modulated sinewave to the phasemeter input.
- 2) Apply the modulating signal to the scintillation input.
- 3) Adjust the amplitude of the modulated sinewave so that the amplitude of the modulation is equal to the amplitude of the modulating signal.
- 4) Adjust the scaling potentiometers in the phasemeter input AGC circuit until the modulation is a minimum at the circuit output.
- 5) Repeat for the phasemeter and MTF inputs.

The condition specified in Step 3 above must be observed during actual use of the ODP. That is, the operator must adjust the levels of the incoming measurement and scintillation signals such that the amplitude of the modulation is equal to the amplitude of the scintillation signal. If this is not possible, their ratio should be set at some convenient value and the same ratio used in Step 3.

3.0 SYSTEM SOFTWARE

3.1 General Requirements

In this section of the report we discuss the performance requirements of the software systems and indicate in a general way how they were met. These systems control the sampling, digital conversion, labeling and recording of the preprocessed optical measurement signals. The specific performance objectives which they were designed to meet were:

- 1) Sampling of the input data in real-time at the rates necessary to retain all of the desired information.
- 2) Analog-to-digital conversion of the data with high enough accuracy to prevent the loss of significant data.
- 3) Sampling and recording of an input signal, without interruption, throughout the duration of the signal.
- 4) Automatic processing of data derived from analog tape recordings, including search for the start and end of the desired segment of the input signal.
- 5) Labeling of digitized data records and files in accordance with ancillary parameters supplied to the computer via the teletypewriter.
- 6) Recording of the digitized data in a format which is compatible with the input requirements of a GE 645 Computer.

The primary signal input to the computer is the measurement data which are provided by the ODP. The ODP also provides three signals which are used by the computer during the processing of the data. These are:

- 1) A train of 1-second time marks;
- 2) A data-condition level, which is positive for calibration data and negative for optical signal data;

3) A train of uniformly spaced pulses which, for the $\Delta\phi$ and $\Delta\Delta\phi$ data, mark the occurrence of each new phase angle measurement, and for the MTF data mark the start of each new MTF cycle. These signals are entered into the computer via a multiplexer which, under control of the software, selects one of them and feeds it to the sampler.

During the performance of an experiment all four signals are recorded by the Ampex FR 106 instrumentation tape recorder onto four separate tracks on a reel of 1-inch wide magnetic tape. The data and the data-condition level are recorded in FM mode, the pulse trains in AM mode. Since the scintillation signal is obtained simultaneously with any one of the other optical measurement signals, it can be recorded on a fifth track, simultaneously with the recording of the data signal. When it is determined that the conditions for an experiment are satisfactory, the calibration button on the preprocessor is depressed for several seconds and then released. The button is again depressed at the conclusion of the experiment. The computer program will sample, convert, and record both the calibration and the real measurement data provided by the preprocessor. Thus, the digital tape recordings will contain calibration data at the beginning and end of a run. These can be used to establish the calibration of the experimental data and to correct the calibration for small drifts which may have occurred during a run.

Two software systems were developed, one for the $\Delta\phi$, $\Delta\Delta\phi$, and scintillation data (Optical 1), and the other for the MTF data (Optical 2). While they contain many of the same subroutines, they differ in the all important routine for sampling the optical data and extracting the desired information.

3.2 Techniques for Meeting the General Performance Requirements

3.2.1 Real-Time Sampling

The design of the procedures for sampling the data in real time required first a determination of whether the data signal supplied by the ODP was to be sampled synchronously or asynchronously. Asynchronous sampling is independent of the frequency of the information carrier and of the measurement rate of the preprocessor. In accordance with the Nyquist criterion, asynchronous sampling must be performed at a rate that is at least twice the information bandwidth. Synchronous sampling, on the other hand, is performed at either the frequency of the carrier, or at the rate of the data measurement outputs of the ODP.

For the scintillation signal, there was no choice but to use asynchronous sampling. The bandwidth of the scintillation data is about 2 kHz, which implies a minimum sampling rate of 4 kHz. This was easily achieved by the techniques which are described in Section 4.

The $\Delta\phi$ and $\Delta\Delta\phi$ signals could have been sampled asynchronously if the information bandwidth were known. However, since one of the objectives of the research program is to determine this bandwidth, there was no choice but to sample these data synchronously. Doing so insures that information at frequencies up to one-half the data measurement rate will be preserved. The highest phase angle measurement rate occurs for the $\Delta\phi$ data, at a reticle speed of 1800 rpm. For the IR measurements this rate is 4.7 kHz. For the VISIBLE it would be 32 kHz if measurements were made every six cycles of the square wave input to the ODP, as it is for the IR data. Since this rate is far higher than can be achieved by the PDP-8 system, the VISIBLE

$\Delta\phi$ measurements are made every 20 cycles when using the highest reticle speed, resulting in an upper measurement rate of 9.6 kHz.

Sampling of the MTF posed a different sort of problem. Because the frequency of the square-wave whose envelope is the MTF varies over a very wide range, it is not possible to sample this function synchronously. On the other hand, the information bandwidth is much wider than can be sampled asynchronously. It is desirable to preserve variations in the MTF whose duration may be only one to two percent of the full MTF cycle. Since two MTF cycles occur per reticle rotation, the bandwidth (of the smallest) of these variations, at the highest reticle speed, is $\frac{1}{0.01 \text{ cycle}} \times 2 \frac{\text{cycles}}{\text{rev}} \times 30 \frac{\text{rev}}{\text{sec}} = 6 \text{ kHz}$. To preserve this data would require a sampling rate of 12 kHz. While it is marginally possible to achieve this rate, it might not be reliable. Moreover, at that sampling rate, a reel of digital magnetic tape could store no more than two minutes worth of data. The solution to the problem of sampling the MTF data was to develop a method in which the signal is sampled asynchronously at a sufficiently high rate, but only the samples needed to define the envelope are stored. The sampling is made synchronous with the MTF waveforms by numbering the samples consecutively from the start of each waveform. Details of this procedure are given in Section 5.

3.2.2 Sampling Accuracy

The A/D converter in the PDP-8 system is capable of up to 12-bit sampling accuracy. However, the time to complete such a conversion, 35 usec, is far too great to permit achieving the desired data sampling rates. Actually, the $\Delta\phi$ and $\Delta\Delta\phi$ data which are provided by the ODP are known to be accurate to one bit in eight. Hence, sampling them with 9-bit accuracy insures that no significant errors will be introduced by the sampler. If the

MTF and scintillation data are obtained from analog tape recordings then 9-bit sampling accuracy will suffice for them also, since the dynamic range of the instrumentation tape recorder is about 42 dB (which is equivalent to 1-bit in eight). While it might be desirable to sample these data with higher accuracy when they are obtained live, it is not possible to do so and still retain real-time sampling at the highest required sampling rates. The time to complete an A/D conversion is 13.5 usec at a sampling accuracy of 9 bits. It jumps to 17 usec at 10 bits, to 25 usec at 11 bits, and to 35 usec at 12 bits. Such increases in the conversion time can be tolerated only at the lower two reticle speeds.

3.2.3 Continuous Sampling and Recording

To achieve continuous computer processing of the optical data, two equal-sized areas (data-buffers) are reserved in the computer memory. Data samples are stored in successive locations in a buffer until it is filled. Then, while the contents of the buffer are being written onto tape, the alternate buffer is filled. The ability to use the two buffers alternately for storing and recording the sample data requires that two conditions be met:

- 1) The time required to record the contents of a buffer, including the time to start and stop the tapewriter, must be less than the time required to fill the buffer.
- 2) The time required to set up the write instructions for the tapewriter controller must be less than the time between two successive data samples. Otherwise, the interval between the last sample in one buffer and the first sample in the alternate buffer will be greater than the average sampling period.

The first of these conditions is met by making the buffer size sufficiently large. The time to start and stop the tape drive is about 15 msec. Data are written onto the tape at a rate of 25 usec per 6-bit byte, which is 50 usec per computer word. Data are stored in the buffer at sampling rates up to about 10 kHz, i.e., 100 usec per sample. Therefore, the minimum length of the buffer, L, with one computer word used per sample, can be computed from

$$\text{load time} = 100 \cdot L \text{ usec}$$

$$\text{unload time} = (15000 + 50 \cdot L) \text{ usec}$$

Solving for L, we find that it is 300 words. Actually, to use the tape efficiently, the buffer size is made about 1600 words. This requires about six inches of tape per record, including the standard 3/4-inch record gap. Thus, a maximum of 4600 records can be written onto a 2400-foot reel of tape. For convenience in checking for potential tape overruns, the maximum number of records is set at 4096.

3.2.4 Automatic Processing of Analog Recorded Data

The main reason for providing automatic processing of analog recorded data is to enable the system to process corresponding time-segments of different data signals which were recorded simultaneously. For example, it may be desirable to compare the MTF data which were obtained for visible and for infra-red light at the same time, or to compare the scintillation data with one of the other data signals obtained for the same laser beam. The automatic processing technique enables the computer to locate the point at which a desired data segment begins, and to process the data for the desired duration of the segment.

To achieve this operation the user enters the following information at the start of a run:

1) The number of data runs which precede the one of interest.
(Actually, the number of sets of calibration data, since each run is preceded by a set of calibration data.)

2) The elapsed time from the start of the data run to the segment of interest.

3) The duration of the segment.

The computer is programmed to detect the start and end of each set of calibration or signal data and to differentiate between the two types. When a run is begun, the analog tape is started and the program proceeds to count the number of calibration sets until the one which precedes the desired data set is detected. It then samples and records the calibration data and it counts the number of data sync pulses in a one-second interval. It uses this to compute the number of digital records that will have to be written for the selected duration of the data set. If this exceeds 4096, the maximum number that can be recorded on a reel of tape, it rewinds the digital tape, computes the maximum run duration for the observed sync-pulse rate, informs the user of that maximum, and requests that a new value of run duration be entered. If the run duration is acceptable, the program counts down the time from the end of the calibration data which precedes the desired data set to the start of the data, using the value of start time entered by the user. Time is counted down in 1-second intervals by using the 1-second time marks which were recorded onto the analog tape simultaneously with the data and sync-pulses. After the desired amount of time has elapsed, the computer proceeds to sample and record the data, using the

sync-pulses to maintain synchronous sampling of the data. Just before recording each record, the computer checks to insure that all the samples in the buffer represent signal data. If the calibration set which succeeds the selected data is encountered before the desired length of run has elapsed (i.e., if the run duration was longer than the extent of the segment of signal data that are being sampled), the computer automatically samples and records this final calibration data set and terminates the run. Otherwise, the computer continues the run until the previously calculated number of records have been written, and then searches for the calibration set which succeeds the run. After sampling and recording this set, the computer writes an end-of-file mark on the digital tape and rewinds the tape.

3.2.5 Labeling of Records

In addition to the data which the user is required to enter for automatic operation of the system, he also can enter data which are used to label and identify the run, and the conditions under which it was made. This additional, ancillary information consist of the following:

- | | | |
|---------------------|---|---|
| Date of the run | - | month, day, and year as two-digit numbers |
| Time of the run | - | hours and minutes as two-digit numbers |
| Type of signal data | - | a two-digit number which can be used to identify the optical data |
| Sampling accuracy | - | a two-digit number corresponding to the setting of the A/D converter |
| Comments | - | a statement of up to 250 words describing the condition of the experiment |

This information, together with the number of calibration sets preceding a run, the time to the start of the data set, and the duration of the run, are recorded in a digital record which is written before the run is started. During the run, the sequence number of each record is entered as ancillary data at the end of the record.

4.0 DESCRIPTION OF OPTICAL 1

In this section of the report we describe in detail the major routines which are used by the program for sampling the phase measurement and scintillation data. A complete listing of the program is presented in Appendix 2 and should be used in conjunction with the flowchart and explanations which follow. Some of the routines which are used in the program are virtually self explanatory, and so will not be described here. Included among these are the service routines for printing various messages on the teletypewriter (TTY), for reading either numbers or Hollerith data entered via the TTY, for converting from octal to binary for BCD printout of computed data, and for writing an end-of-file and rewinding the magnetic tape.

4.1 The Main-Line Routine

The main-line routine is the set of instructions, stored in locations 200 through 257, which control the flow of operations in this data sampling program. It calls upon the supporting subroutines as they may be required. A flowchart is presented in Figure 10.

The first step is a call to subroutine STRTUP which initializes certain parameters, requests the input of other parameters, and reads, stores, and records these data. Once this is accomplished, the program halts to permit the operator to check the equipment from which the optical data signal will be obtained.

When the system is ready, the operator depresses the RUN switch and the program continues with the sequence of six instructions which start with the label CALTS. Their purpose is to count down the number of sets of calibration data which precede the desired signal data. This number, entered by the operator during the STRTUP routine, is incremented by one, negated, and

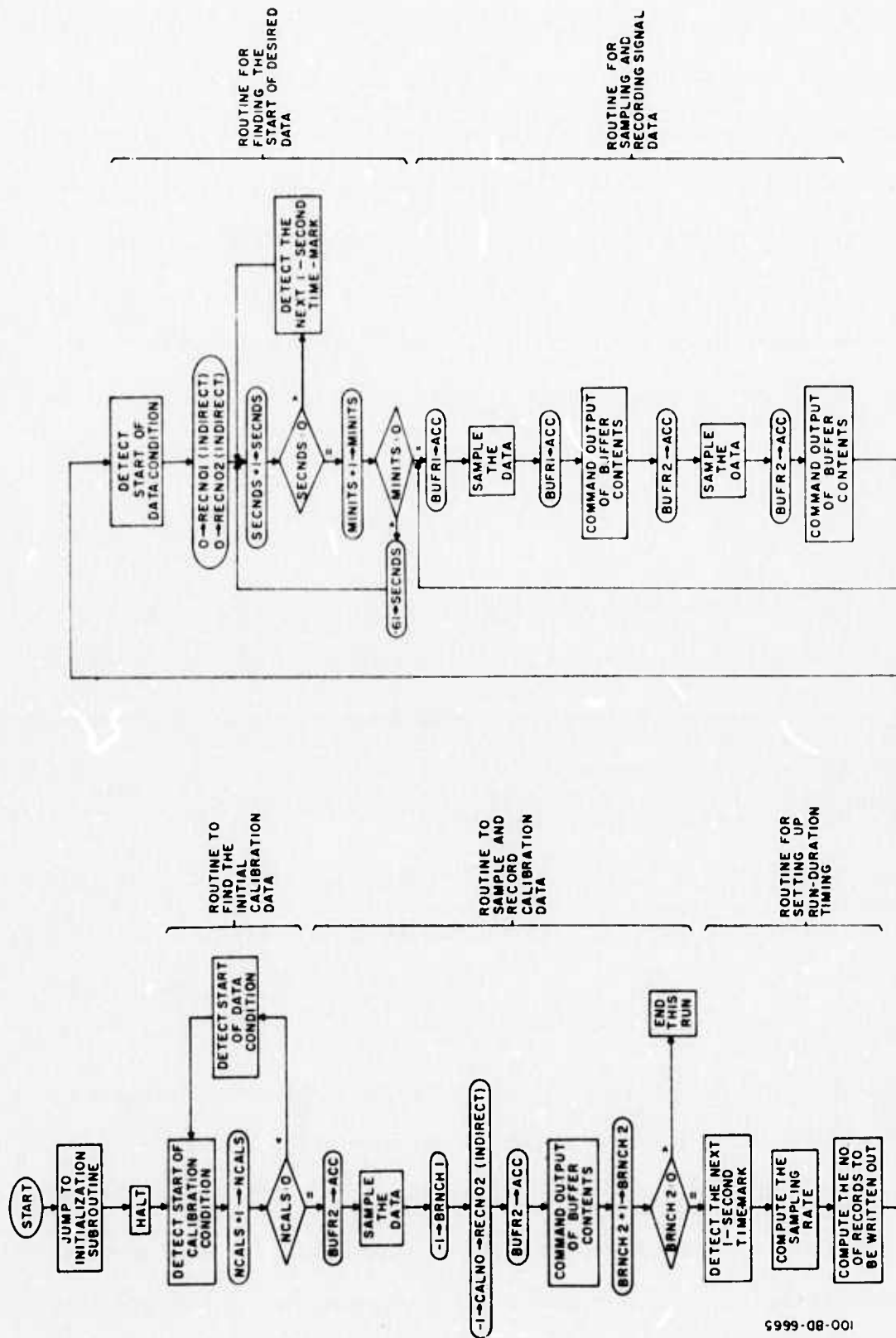


FIG. 10 EXECUTIVE ROUTINE FOR OPTICAL I

stored in NCALS (at location 1026). The start of a set of calibration data is detected by subroutine CALTST, and the end (i.e., the start of a data set) by DTATST. When NCALS reaches zero the program branches to CALSET to sample the calibration data. A -1 is stored in BRNCH1 to indicate that the calibration data were not encountered during the sampling of the desired signal data. A -1 is also stored in RECNO2, which is the address in Buffer 2 at which the record sequence number is stored. Finally, the contents of Buffer 2 are written onto tape by a call to subroutine BUFOUT. On return from this routine, BRNCH2, which was set to -1 by the initialization routine, is incremented and the mainline program skips the next instruction. At the end of the run the calibration data set which follows the signal data will be sampled and recorded. For this set a -2 will be stored in RECNO2. This time when BRNCH2 is incremented the instruction at 225 will not be skipped and the program will branch to the routine FINIS which writes an end-of-file on the digital tape and then rewinds the tape.

After writing out the initial calibration record the mainline program calls subroutine TICTOC which detects the leading edge of the next one-second mark pulse to be generated by the preprocessor. It then calls subroutine SAMPRT which determines the data sampling rate by counting the number of sample-sync pulses which are generated by the preprocessor in the next one-second interval. The program uses this information in subroutine RECONT to compute the number of records of signal data which will be written for the selected run duration. This number is negated, stored in NRECS, and counted down during the run to determine when the run should be terminated.

All of the foregoing operations are performed within the duration of the initial calibration data set. Consequently, the next instruction, at

231, is a call to DTATST to detect the start of the signal data. After clearing the addresses at which the record sequence number is stored in both buffers, the program proceeds to count down the time to the start of the desired section of the signal data. The time, in minutes from the end of the initial calibration data set, had been entered by the operator during the initialization routine. The initialization routine incremented this number by one, negated it, and stored it in STRTIM. It also stored a -1 in SECNDS. Consequently, when the set of ten instructions which begins at 234 is entered the first instruction results in a jump to MINITS where STRTIM is incremented. If the value of STRTIM has not been reduced to zero the program stores a -61 in SECNDS and returns to 234. SECNDS is incremented and then reincremented at the start of each succeeding one-second time mark until it reaches zero, when STRTIM is again incremented.

The procedure described above is repeated until STRTIM reaches zero, whereupon the program jumps to the main data-sampling routine. Here the program first loads samples into Buffer 1. When the buffer is filled, the writing out of its contents is initiated by a call to subroutine BUFOUT. At the same time, the program begins to load Buffer 2. The buffers continue to be loaded and unloaded in alternation, until the requisite number of records has been written. The program then jumps back to instruction LSTCAL, at 210, to detect, sample, and write out a record of the calibration data which follows the signal data. If the computer encounters the final set of calibration data before the value of NRECS has been counted down to zero, the sampling of signal data is automatically terminated and the program jumps to 211.

4.2 Subroutine to Sample the Data (SAMPLE, at location 302)

This subroutine samples the data on Channel 1 whenever it detects a sync pulse on Channel 0. In this way we insure that the sampling of the data will be synchronous with the availability of a new measurement by the ODP and will occur after all transients have disappeared. When the subroutine is entered the accumulator will contain the address of the first location preceding Buffer 1 or Buffer 2, whichever one is to be filled. This is deposited in the autoindexing register at location 10. The negative number of samples to be stored in the buffer, NSAMPS (= -1620), is deposited in IX1. The program then sets the multiplexer address to Channel 0 and repeatedly samples the sync-pulse signal until a positive level is detected. It then sets the multiplexer to Channel 1, samples the data signal, and stores the sample indirectly in the address indicated in location 10. The number of samples, in IX1, is incremented, and if it is not zero, the program returns to DATAIN (at 306) to detect another sync pulse. This sequence of operations is repeated until the contents of IX1 reaches zero, when the multiplexer address is set to Channel 2, in preparation for testing whether the computer encountered calibration data during the loading of the buffer. Finally, the record sequence number is incremented in both buffers and the subroutine is exited.

4.3 Subroutine to Write Digital Tape Records (BUFOUT, at location 331)

When this routine is entered the accumulator contains the address of the first location preceding the buffer which is to be unloaded. This number is stored indirectly at the address stored in CALOC for use by the Tape Controller Unit (TCU). The program also stores -1626, the negative of the number of computer words in each buffer, in WCLOC. This is counted down by

the TCU during the transfer of data. The computer is then instructed to sample the data condition line (the multiplexer address having previously been set to Channel 2 at the end of the data sampling routine). While the analog-to-digital conversion is being completed, the command word to write 556 bits per inch in odd parity on tape unit 0 is loaded into the TCU. The output of the A/D converter is then read. If it is positive, indicating that calibration data was encountered, the routine is immediately exited via BUFOUT1 without writing the data onto the tape. However, if, as expected, the A/D output was negative, indicating optical signal data, the command to write the tape, MTGO, is issued. From here on the transfer of the data in the buffer will occur automatically, under control of the TCU. Before leaving this subroutine the number of records to be written, NRECS, is incremented and, if it is not zero, a normal exit occurs. When NRECS is reduced to zero the program jumps to LSTCAL to terminate the run in a normal manner.

4.4 Subroutine to Detect the Start of a Calibration Data Set (CALTST, at location 260)

The type of data being read by the computer is indicated by a DC level on Channel 2. A negative level indicates signal data, a positive level indicates calibration data. Subroutine CALTST locates the start of calibration data by detecting the point at which the level on Channel 2 switches from negative to positive. To prevent errors in identifying the start of a calibration data set, particularly for data reproduced from analog tape recordings, a detection is confirmed only after 3247 successive positive samples have been taken following a negative sample.

4.5 Subroutine to Detect the Start of Optical Signal Data (DTATST, at location 273)

This routine is similar to the preceding one with the exceptions that a change from a positive to a negative DC level is sought and that one negative sample preceded by a positive sample is sufficient to confirm the detection.

4.6 Subroutine to Detect One-Second Time Marks (TICTOC, at location 1103)

This routine detects the leading edge of the time-mark pulse which is generated by the preprocessor. As in the case of subroutine CALTST, detection occurs when a negative sample is followed by a positive one. At the start of this routine the address at which negative samples are stored, NOTIK, is cleared. Consequently, if the first sample should be positive the decision is not made that a time-mark pulse was detected. This is necessary to insure that detection occurs only at the leading edge of the pulse.

4.7 Subroutine for Computing the Sampling Rate (SAMPRT, at location 1125)

This subroutine is called by the mainline program immediately after a time-mark pulse has been detected. When in this subroutine, the computer alternatively samples the sync-pulse data on Channel 0, and the time-mark data on Channel 3, incrementing a count each time a sync pulse is detected. Since sync-pulse rates up to 10 kHz can occur, a double-precision counter is used, with the 16 lower-order bits in SRATLO and the 16 higher-order bits in SRATHI. The count is incremented at each sync pulse until a time-mark pulse is detected.

Because the sync pulses could occur at intervals of 100 usec it was necessary to minimize the time needed to sample the time-mark data and to test for the leading edge of a time-mark pulse. This was accomplished by having the program first seek a negative time-mark level, thereby de-

tecting the end of the time-mark pulse which preceded the entry of this routine. At the first negative time-mark sample, the instructions inside the routine are altered so that the program thereafter seeks a positive time-mark level. In this way, it is not necessary to repeatedly check the polarity of the last sample each time a new one is tested, as is done in subroutine CALTST and TICTOC.

5.0 SAMPLING AND RECORDING THE MTF SIGNAL (SAMPLE, AT LOCATION 1211)

The instructions which control the sampling and recording of the MTF signal are stored starting in location 1200 (see Appendix 3). These nine instructions, which alternately load and unload the data buffers, are the same as the ones used in the mainline routine of OPTICAL 1 for acquiring and recording optical phase-angle and scintillation data. (See Figure 10 and Appendix 2, locations 247 through 257.) As in the case of OPTICAL 1, subroutine SAMPLE is entered with the accumulator containing the address of the first location preceding the buffer to be loaded.

The first step in Subroutine SAMPLE is to store this address in auto-indexing register 10. The address is then retrieved and the offset from the start of the buffer to the region where the sync-pulse peak-sample locations are stored is added to it. The sync pulses are located by relating them to the number of the MTF peak sample at which they were detected. The resulting sync-array address is then loaded into auto-indexing register 11. Next, the sample-number counter is cleared, the maximum number of sync pulses per buffer is stored in SYNCNO, and the maximum number of MTF peaks per buffer is stored in PEAKNO. (Note that both of these numbers are negative.)

At this point the program tests to see whether the previous exit from Subroutine SAMPLE was a normal one. That is, whether the program exited when the maximum permissible number of sync pulses had been counted down to zero. If it did, then a zero would have been stored in EXITST and the program therefore will begin the MTF sampling operation by a jump to the instruction labeled LOOP, at location 1264. However, if the routine had been exited because the maximum permissible number of MTF peaks per buffer had been counted down to zero (i.e., the buffer had been filled), then a -1 would have been

stored in EXITST. In that case, the program will jump to MFTST in order to resynchronize the sampling with the start of the next MTF sync pulse. When that pulse is detected the program resumes by clearing SAMPL1, where the amplitude of the last MTF data sample is stored, ZROSLP, where a count of equal-amplitude samples is stored, and UPSLP, which is an indicator of a positive slope on the MTF signal. The program then jumps to LOOP.

5.1 The MTF Sampling Program.

The program that controls the sampling of the MTF signal is listed in Appendix 3. However, this standard listing of the program as it actually is stored in the PDP memory is not well suited for an explanation of how the program operates. A far more useful listing, in semi-flowchart form, is presented in Figure 11. The instructions are separated into sets which are denoted by square brackets on the left and braces on the right. The operation being performed or the condition encountered is indicated to the right of the square bracket. The time taken for each instruction, in microseconds, is indicated to the right of the instruction. The total time taken for the execution of a set is noted by the circled number to the right of each brace.

Entry to this routine normally occurs at the instruction labeled LOOP, at location 1264. This instruction clears the multiplexer to Channel 0 in preparation for sampling the MTF data signal. While the multiplexer is settling, the contents of the accumulator are deposited in TEMP2. (Normally, at this time the accumulator would contain the value of the previous sample of the MTF sync-pulse signal.) The accumulator is then incremented so that on the subsequent call to Subroutine DELAY, the program will idle for 10.5 usec. On return from DELAY, the program jumps to MTFSP at 1232, which is the true start of the sampling loop.

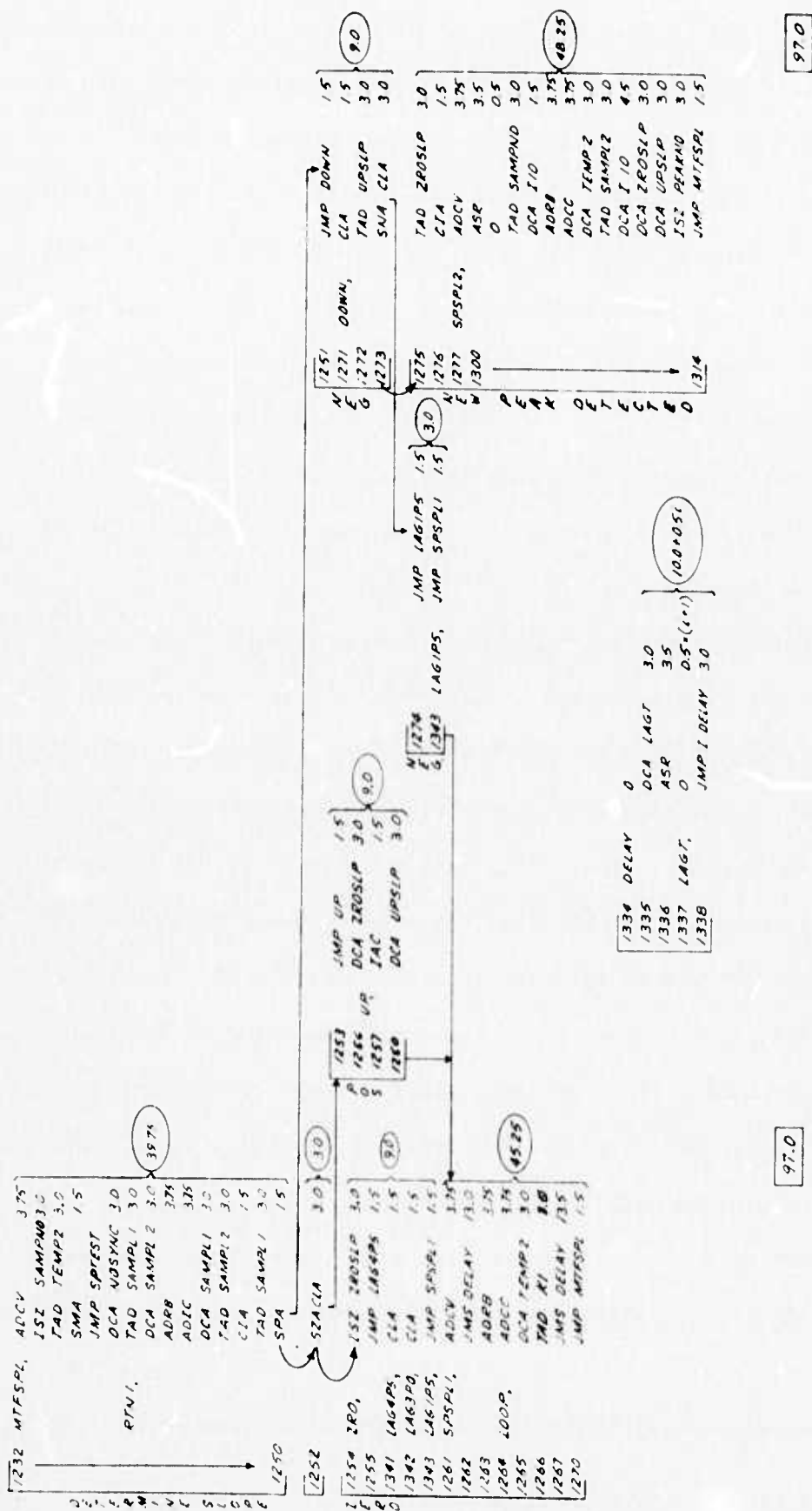


FIG. II PROGRAM FLOW-PATH AND TIMING OF MTF SAMPLING ROUTINE

At this point the program samples the MTF signal line and immediately increments the sample count number (SAMPNO). While awaiting completion of the A/D conversion, the previous sync-pulse sample, stored in TEMP2, is returned to the accumulator. If the contents are positive, indicating that a sync pulse may have been detected, the program jumps to SPTEST. Otherwise, the negative value is deposited in NOSYNC to be used in a future test for a sync pulse. The program continues by transferring the previous MTF data sample from SAMPL1 to SAMPL2. It then reads the contents of the A/D buffer which by this time will contain the value of the latest MTF data sample. The multiplexer address is then incremented in preparation for sampling the MTF sync-pulse signal on Channel 1.

The next four instructions are designed to determine the slope at the sampled point on the MTF waveform. First, the contents of the accumulator are deposited temporarily in SAMPL1 and the previous sample, stored in SAMPL2, is returned to the accumulator and its value made negative. The value of the current sample is then added to the contents of the accumulator. If the sign of the resultant is negative, the program jumps to DOWN at 1271 to determine whether a new peak has been detected. If the sign was positive the program, at 1252, first checks to determine if the value of the resultant was greater than zero. If it was, the program jumps to UP where it clears the zero-slope counter (ZROSLP) and puts a 1 in the up-slope indicator (UPSLP). It then continues with instruction 1261.

If the value of the resultant was zero, the computer may have been sampling the MTF signal at a flat or very slowly changing peak. In order to properly locate the center of the peak in such a case, it is necessary to know how many successive equal-amplitude samples occurred immediately before

the peak was detected. Accordingly, the count of the number of zero-slope samples, ZROSLP, is incremented. Now, in order to make the time taken in this path equal to the time taken if the resultant had been positive, the program jumps to LAG4P5, to idle for 4.5 usec. As a result, the total time in either path is 9.0 usec.

The program continues by sampling the MTF sync-pulse signal. It then idles for a total of 13.0 usec in order to partly equalize the time taken in this path with the time taken when a new peak is detected. At the end of this delay the contents of the A/D buffer are read and the multiplexer address is cleared to zero in preparation for sampling the MTF data line. The contents of the accumulator are stored in TEMP2, the accumulator is incremented, and the program delays for 13.5 usec to complete the equalization of path timing. The program then jumps back to MTFSP1.

If, at the instruction located 1250, the computer detected that the previous sample was, in fact, larger than the current one, the program jumps to DOWN, at 1271. There, the accumulator is cleared and the current value of the up-slope indicator is obtained. If its value is zero, it indicates that this is at least the second successive sample on a downward sloping segment of the MTF signal, and that therefore a new peak has not been detected. In that case, the program jumps to LAG1P5 in order to insure that the total time taken in this path is the same as the time taken when either an up-slope or a zero-slope is detected. On the other hand, if the up-slope indicator is not zero, it indicates that the previous sample was on either a positive or zero slope and, therefore, a new peak has been passed. In that case, the program continues with the set of instructions which are stored in locations 1275 through 1314.

First, the count of zero-slope samples is brought to the accumulator where its sign is made negative. At this point, the A/D converter is commanded to begin the sampling of the MTF sync-pulse signal. The negative zero-slope count is divided by two, by shifting the contents of the accumulator one position to the right, and the current value of the sample number is added to the resultant. The number that is obtained is the sample number at which the peak was detected. Thus, if the zero-slope count was zero, the peak is located at the current sample. Alternatively, if the zero-slope count was not zero, the peak is located midway in the preceding string of equal amplitude samples. The location of the peak is stored at the address contained in auto-indexing register 10. At this point, the contents of the A/D buffer are read and the multiplexer address is set to zero in preparation for sampling the MTF signal line. The accumulator now contains the value of the current sample of the sync-pulse line. This is stored in TEMP2. Next, the amplitude of the newly detected sample is stored in the next available buffer address, as indicated by the contents of auto-indexing register 10. Finally, the zero-slope count and upslope indicator are zeroed and the count of the number of detected peaks is incremented. The program then returns to MTF SPL.

The exit routine for Subroutine SAMPLE begins at location 1320. There are two ways of getting to this point. The first, on a normal exit, occurs when the sync-pulse count has reached zero. (The negative sync-pulse counter is incremented on each detection of an MTF sync-pulse in routine SPTEST, as described in Section 5.2.) The second, or abnormal exit, occurs when the negative peak-number count, which is incremented at location 1312,

has reached zero. Should this occur, the maximum permissible number of sync pulses per buffer is reduced by one to protect against an abnormal exit on the succeeding buffer cycle. (If this number should ever reach zero, the program will halt with 7171 in the accumulator.)

The program arrives at EXIT with a -1 in the accumulator for an abnormal exit, and a zero for a normal one. The first step in the exit routine is to deposit the contents of the accumulator in EXITST for use upon the next entry to subroutine SAMPLE. It then fetches from auto-indexing register 11 the address of the last sync-pulse number to be stored in the buffer and obtains at that address the number of the last MTF signal peak to be detected. This number is then stored in Buffer 1 at the address indicated by NPKSB1, and in Buffer 2 at the address indicated by NPKSB2. The multiplexer address is then set to 2, in preparation for sampling the data condition on Channel 2 during execution of Subroutine BUFOUT. Finally, the program increments the record-number count in both buffers and then exits.

The techniques used for equalizing the running times of the program insure that whichever possible sequence of paths is taken the total time between successive samples of the MTF signal will be a constant 97.0 usec. This corresponds to a sampling rate of about 10.3 kHz, which is adequate for extracting all of the useful information in the modulation transfer function. The regularity of the spacing between samples during each MTF cycle makes it possible to accurately reconstruct the envelope of the MTF square-wave signal.

It should be noted at this point that in the event that the jump at location 1236 to test for the presence of an MTF sync pulse is executed, the time between the previous sample and the next one to be taken will be great-

er than 95.5 usec. If, in fact, a sync pulse is detected, the spacing between these two samples will be increased by 24 usec. In any event, since sync pulses occur only at the boundaries between successive MTF cycles the effect of the increased interpulse spacing would be to vary the time spacing between the origins of successive MTF waveforms. However, since such a variation could not exceed 24 usec, or one-fourth the normal sampling interval, it is apparent that this effect can be neglected.

5.2 The MTF Sync-Pulse Test (SPTEST at location 1347)

The procedure used for testing for the start of an MTF sync pulse is exactly the same as was used in OPTICAL1 for detecting the start of a 1-second time-mark pulse. However, when a sync pulse is detected this subroutine does not immediately return to the program which called it. Instead, it first increments the sync-pulse counter. If the counter has not reached zero the subroutine continues by bringing in the number of the most recent MTF peak to be detected, changes the sign of the number, and stores it at the address indicated by auto-indexing register 11. The subroutine then returns to the calling program. In the event that the sync-pulse count has reached zero, the subroutine jumps to EXIT at location 1320.

6.0 APPENDIX 1

PIN CONNECTIONS FOR EXTERNAL PHASE-ORIGIN DATA

(Connector on rear panel of the ODP)

<u>Pin</u>	<u>Data</u>
A	2^0
B	2^1
C	2^2
D	2^3
E	2^4
F	2^5
H	2^6
J	2^7
K	2^8
L	2^9
M	2^{10}
N	2^{11}
P	<u>Reset</u>
R	+5
S	Ground

- Notes:
1. External input data must be switched between 0 and 5 volts.
 2. If external inputs are used (Pins A-N) IC3 and IC7 must be removed to prevent damage.
 3. When external inputs are not used, Pin P may be grounded to produce a zero origin.

7.0 APPENDIX 2

LISTING OF OPTICAL 1 PROGRAM
FOR SAMPLING AND RECORDING OPTICAL DATA

LOCN CONT LABEL LIST

*C					
00000	0000				
00001	5402			JMP I 2	
00002	0000				
00003	0000	IA1,			
00004	0000	IA2,			
00005	0000	IA3,			
00006	0000	TEMP1,			
00007	0000	TEMP2,			
*20					
00020	0000	DATE,			
00021	0000				
00022	0000				
00023	0000	TIME,			
00024	0000				
00025	0000	CODE,			
00026	0000	NCALS,			
00027	0000	STRTIM,			
00030	0000	RUNTIM,			
00031	0000	ABITS,			
/					
00032	4634	ASAPPS,	-3124		
00033	0000	NRECS,			
00034	0000	SRATH1,			
00035	0000	SRALD,			
/					
00036	1523	EUFRL,	1523		
00037	4646	SRTHE1,	4646		
00040	4647	SRTLE1,	4647		
00041	4650	ARCSB1,	4650		
00042	4651	RECND1,	4651		
00043	4651	EUFRL2,	4651		
00044	7774	SRTHE2,	7774		
00045	7775	SRTLE2,	7775		
00046	7776	ARCSB2,	7776		
00047	7777	RECA02,	7777		
00050	4652	WDC01,	-3126		

/PRE-ORIGIN OF BUFFER 1

/PRE-ORIGIN OF BUFFER 2

/1626 WORDS PER BUFFER (=542 GE COMPUTER WORDS)

00051	1532	CALBFL, 1532	/ADDRESS OF NCALS IN BUFFER 1 FOR TAG WRITEOUT.
*70			
00070	0000	ERNCH1, 0	/USED IN TESTS FOR THE INITIAL AND FINAL CAL
00071	0000	ERNCH2, 0	/GROUPS. BOTH ARE SET TO -1 INITIALLY.
00072	0000	CALND, 0	
00073	7777	SECONDS, -1	
00074	0000	CALCNT, 0	
/			
00075	0002	K2, 2	
00076	0003	K3, 3	
00077	0017	K17, 17	
00100	0026	K26, 26	
00101	0027	K27, 27	
00102	0033	K33, 33	
00103	0260	K260, 260	
00104	7777	M1, -1	
00105	7776	M2, -2	
00106	7775	M3, -3	
00107	7774	M4, -4	
00110	7773	M5, -5	
00111	7767	M11, -11	
00112	7766	M12, -12	
00113	7765	M13, -13	
00114	7764	M14, -14	
00115	7703	M75, -75	
00116	7521	M257, -257	
00117	7520	M260, -260	
00120	4654	M3124, -3124	
/			

*20C						
00200	4777	JMS	STRTUP	/SET	PARAMETERS AND READ IN RUN DATA.	
00201	7402	HLI				
00202	4260	JMS	CALTS1	/FIND	THE START OF THE NEXT CAL GROUP.	
00203	2026	ISZ	NALCS	/LAST	CAL GROUP BEFORE SELECTED DATA....	
00204	5206	JMP	+2	/NO	TRY AGAIN.	
00205	5212	JMP	CALSET	/YES	GO AHEAD.	
00206	4273	JMS	STATST	/FIND	THE END OF THIS CAL GROUP.	
00207	5202	JMP	CALTS	/TRY	AGAIN.	
/						
00210	4260	LSTCAL, JMS	CALTS1	/DETECT	THE FINAL CAL GROUP.	
00211	4776	JMS	ENDLAG	/DELAY	200 MSEC IN CASE BUFFER 2 IS IN USE.	
00212	1043	CALSET, IAD	RUF2			
00213	4302	JMS	SAMPLE			
00214	7040	GMA				
00215	3070	DCA	BRNCH1	/SET	BRNCH1=-1 FOR NORMAL RETURN FROM BUFOUT.	
00216	2072	ISZ	CALND	/CALND	= 1 FOR INITIAL CAL GROUP	
00217	1072	IAD	CALND	/	= 2 FOR FINAL CAL GROUP.	
00220	7041	CIA		/CHANGE	SIGN OF CALND AND STORE	
00221	3447	DCA	I RECND2	/AS	RECORD NO. IN BUFFER 2.	
00222	1043	IAD	RUF2			
00223	4331	JMS	BUFOUT			
00224	2071	ISZ	BRNCH2	/SKIP	IF THIS WAS THE INITIAL CAL GROUP.	
00225	5357	JMP	FINIS			
/						
00226	4775	JMS	TICTOC	/FIND	THE START OF THE NEXT ONE-SECOND TICK	
00227	4774	JMS	SAMPRT	/COMPUTE	THE SAMPLING RATE	
00230	4773	JMS	RECONT	/COMPUTE	THE NO. OF RECORDS FOR THIS RUN (NRECS)	
00231	4273	JMS	STATST	/FIND	THE END OF THIS CAL GROUP.	
00232	3442	DCA	I RECND1	/CLEAR	THE RECORD NUMBER COUNTERS.	
00233	3447	DCA	I RECND2			

/ ROUTINE TO FIND THE START OF DATA

```

00234 2073 STARTS, ISZ SECS
00235 5237 JMP +2
00236 5241 JMP MINIS
00237 4775 JMS TICIEC
00240 5234 JMP STARTS
00241 2027 MINIS, ISZ STRIN
00242 5244 JMP +2
00243 5247 JMP GETOTA
00244 1115 IAC M75
00245 3073 DCA SECS
00246 5234 JMP STARTS

```

/ FIND THE NEXT 1-SECOND TIME MARK.

/ MAINLINE ROUTINE

```

00247 1036 GETOTA, IAD BUF1
00250 4302 JMS SAMPLE
00251 1036 IAD BUF1
00252 4331 JMS BUFOUT
00253 1043 IAD BUF2
00254 4302 JMS SAMPLE
00255 1043 IAD BUF2
00256 4331 JMS BUFOUT
00257 5247 JMP GETOTA

```

/ WRITE OUT BUFFER 1

/ WRITE OUT BUFFER 2.

/ ROUTINE TO DETECT THE START OF A CALIBRATION GROUP

```

00260 0000 CALIST, C
00261 1036 IAD BUF1
00262 3074 DCA CALCT
00263 6532 ADCV
00264 4772 JMS LAG4
00265 6534 ADDB
00266 7710 SPA CLA
00267 5261 JAP +5
00270 2074 ISZ CALCAT
00271 5263 JMP +6
00272 5600 JMP 1 CALIST

```

/ CAL GROUP IS DETECTED AFTER 3247 SUCCESSIVE
/ POSITIVE SAMPLES ARE TAKEN ON CHANNEL 2.

/ CAL CONDITION IS POSITIVE ON CHANNEL 2.

ROUTINE TO DETECT THE START OF A DATA GROUP

```

00273 0000  LIAISI, C
00274 6532  ADCV
00275 4772  JMS LAG9
00276 6534  ADRB
00277 7700  SMA CLA
00300 5274  JMP 1-4
00301 5673  JMP I DIAISI

```

/DATA CONDITION IS NEGATIVE ON CHANNEL 2

ROUTINE TO SAMPLE THE OPTICAL DATA. THE A/D
CONVERTER IS TRIGGERED WHEN A DATA-STROBE IS DETECTED.

```

00302 0000  SAMPLE, C
00303 3010  DCA IO
00304 1032  IAD ASAMPS
00305 3033  DCA IX1
00306 6541  DATAIN, ADCG
00307 4771  JMS LAG17
00310 6532  ADCV
00311 4772  JMS LAG9
00312 6534  ADRB
00313 7710  SPA CLA
00314 5310  JMP 1-4
00315 6544  ADIC
00316 4771  JMS LAG17
00317 6532  ADCV
00320 4772  JMS LAG9
00321 6534  ADRB
00322 3410  DCA I IO
00323 2003  ISZ IX1
00324 5306  JMP DATAIN
00325 6544  ADIC
00326 2442  ISZ I RECON1
00327 2447  ISZ I RECON2
00330 5702  JMP I SAMPLE

```

/STORE THE PRE-BUFFER ADDRESS.

/STROBES ARE ON CHANNEL ZERO
/DELAY 17 USEC TO ALLOW MUX TIME TO SETTLE.

/DELAY 9 USEC TO ALLOW TIME FOR A/D CONVERSION.

/STROBES ARE POSITIVE
/NO STROBE YET, TRY AGAIN.
/SIGNAL DATA ARE ON CHANNEL 1

/STORE THE SAMPLE IN THE SELECTED BUFFER
/HAS THE REQUIRED NO. OF SAMPLES BEEN TAKEN...
/NO. SAMPLE AGAIN.
/YES. PREPARE TO TEST DATA CONDITION ON CH. 2
/BUMP THE RECORD NUMBER COUNTERS.

/	ROUTINE TO WRITE OUT EITHER BUFFER	
00331	0000	HUFOUT, C
00332	3756	CCA I CALOC
00333	1050	TAD WDCNT
00334	3755	CCA I WCLCC
00335	6532	ADCV
00336	1354	FAD COMAND
00337	6716	MTLC
00340	7200	CLA
00341	6534	ADCB
00342	7700	RECIST, SMA CLA
00343	5350	JMP RFOU11
00344	6722	MTGO
00345	2033	ISZ NRECS
00346	5731	JMP I RUFOUT
00347	5210	JMP LSTCAL
00350	2070	RFOU11, ISZ BRNCH1
00351	5211	JMP LSTCAL+1
00352	6722	MTGO
00353	5731	JMP I RUFOUT
00354	C445	COMAND, C445
00355	7752	WCLCC, 7752
00356	7753	CALOC, 7753
/		
/	ROUTINE TO WRITE END-OF-FILE AND REWIND THE TAPE	
00357	4770	FINIS, JMS MAGTS
00360	C455	C455
00361	4770	JMS MAGTS
00362	C415	C415
00363	7402	HLT
/		
00370	C400	
00371	1157	
00372	1155	
00373	1215	
00374	1125	
00375	1103	
00376	1200	
00377	0410	

TAPE CONTROL ROUTINE FOR EOF AND REWIND

00400	0000	MAGIS, C	JMS	ENDLAG	/DELAY 200 MSEC.
00401	4776		TAC I	MAGIS	
00402	1600				
00403	6716		MILC		
00404	7200		CLA		
00405	6722		MICO		
00406	2200		ISZ	MAGIS	
00407	5600		JMP I	MAGIS	

ROUTINES FOR ENTRY OF PARAMETER DATA AT THE START OF A RUN.

CC415	CC40	SRIOP, C
CC411	4775	JMS INIL1
CC412	4222	JMS PARAMS
CC413	4774	JMS INIL2
CC414	1075	IAD K2

/DATA TYPE IS ON CHANNEL 2.

	IAD BUFL1	/PREPARE TO WRITE OUT IAG DATA
0C416	1C36	
0C417	4777	JMS BUFOUT /GO.
0C420	4773	JMS PRNTO /TYPE... READY
0C421	5610	JVP 1 SRTUP /RETURN TO 201

	JMS ENTER	JMS DATE	JMS NUMBER
00423	4772		
00424	4771	/	XX/YY/ZZ
00425	4264		
00426	7775		-3

00427	4772	JMS ENTER		
00430	4770	JMS TIMNEW	/	XX/YY/
00431	4264	JMS NUMBER		
00432	7776	-2		

00433	4772	JMS ENTER		
00434	4767	JMS DATAID	/	XX/
00435	4264	JMS NUMBER		
00436	7777	-1		
/				
00437	4772	JMS ENTER		
00440	4766	JMS CALGRP	/	XX/
00441	4264	JMS NUMBER		
00442	7777	-1		
/				
00443	4772	JMS ENTER		
00444	4765	JMS STARIM	/	MMM/
00445	4264	JMS NUMBER		
00446	7777	-1		
/				
00447	4772	JMS ENTER		
00450	4764	JMS RNTIME	/	MMMN/
00451	4264	JMS NUMBER		
00452	7777	-1		
/				
00453	4772	JMS ENTER		
00454	4763	JMS IBITS	/	XX/
00455	4264	JMS NUMBER		
00456	7777	-1		
/				
00457	4772	JMS ENTER		
00460	4762	JMS CMNTS	/	ABCD12 345...../
00461	4343	JMS ALPHAB		
00462	4761	JMS CRLF		
00463	5622	PRMRY, JMP I PARAMS		
/				
/				
/				
00464	0000	ROUTINE TO READ N NUMBERS WITH SLASHES AS DELIMITERS		
00465	1664	NUMBER, C		
00466	3003	TAD I NUMBER /FETCH NO. OF NUMBERS TO BE READ		
00467	4312	CCA IX1		
00470	7450	NUMBER, JMS INPNC /READ ONE DIGIT		
		SMA /SKIP IF NOT A SLASH		

00471	5303	JMP NBR2	/IT IS A SLASH. STORE THIS NUMBER.
00472	1117	TAD M260	/REMOVE ASCII CODING AND
00473	3007	LCA TEMP2	/STORE THE NEW DIGIT.
00474	1006	TAD TEMP1	/MULTIPLY SUM OF
00475	7425	MQL MUY	/PREVIOUSLY STORED DIGITS
00476	0012	12	/BY 10.
00477	7501	MQA	
00500	1007	TAD TEMP2	/ADD THE NEW DIGIT AND
00501	3006	DCA TEMP1	/STORE THE NEW SUM.
00502	5267	JMP NBR1	/GO BACK FOR MORE.
00503	1006	NBR2, TAD TEMP1	
00504	3411	DCA I 11	/STORE THE NUMBER
00505	3006	DCA TEMP1	
00506	2003	ISZ IX1	/ANY MORE NUMBERS TO COME.....
00507	5267	JMP NBR1	/YES. GO BACK FOR MORE.
00510	2264	ISZ NUMBER	/NO. BUMP THE RETURN ADDRESS.
00511	5664	JMP I NUMBER	/RETURN.
/			
/ ROUTINE TO READ NUMERIC DATA IN FROM THE TTY			
00512	C000	INPNO, 0	
00513	4335	JMS LISV	/READ IN 1 ASCII CHAR, FROM TTY
00514	3005	DCA IX3	/STORE IT.
00515	1005	TAD IX3	/GET IT BACK.
00516	1116	TAD M257	/GREATER THAN 256.....
00517	7510	SPA	/YES.
00520	5330	JMP REPEAT	/NO. ASK AGAIN.
00521	7450	SVA	
00522	5712	JMP I INPNO	/ACCUMULATOR = ZERO. CHARACTER WAS A SLASH.
00523	1113	TAD M15	/LESS THAN 13.....
00524	7700	SMA CLA	/YES. IT IS A NUMBER.
00525	5330	JMP REPEAT	/NO. ASK AGAIN.
00526	1005	TAD IX3	/GET IT BACK
00527	5712	JMP I INPNO	/DONE.
00530	7300	REPEAT, CLA CLL	
00531	1264	TAD NUMBER	
00532	1106	TAD M3	
00533	3003	DCA IX1	
00534	5403	JMP I IX1	

```

/ ROUTINE TO READ ONE ASCII CHARACTER FROM THE TTY
00535 0000 LISN, C
00536 6031 KSF /SKIP ON KEYBOARD FLAG
00537 5336 JMP -1
00540 6036 KRB /READ KEYBOARD BUFFER AND CLEAR FLAG
00541 6046 TLS /ECHO BACK.
00542 5735 JMP I LISN

```

```

/ ROUTINE TO READ HOLLERITH CHARACTERS (TERMINATION BY A SLASH)
00543 0000 ALPHAB, C
00544 1077 TAD K17
00545 1036 TAD HUFRI
00546 3010 DCA IO
00547 4335 ALFAI, JMS LISN
00550 3006 DCA TEMPI
00551 1006 TAD TEMPI
00552 1116 TAD M257
00553 7650 SNA CLA
00554 1743 JMP I ALPHAB
00555 1006 TAD TEMPI
00556 3410 DCA I 10
00557 5347 JMP ALFAI

```

```

/
00561 1020
00562 0720
00563 0703
00564 0643
00565 0664
00566 0624
00567 0700
00570 0747
00571 0613
00572 0600
00573 0735
00574 1040
00575 1030
00576 1200
00577 0331

```

*600					
00600	0000	ENTER, C			
00601	4777	JMS CRUF			
00602	4776	JMS PRINT			
00603	7772	-6			
00604	C305	E			
00605	C316	N			
00606	C324	T			
00607	C325	E			
00610	C322	X			
00611	0240	SPACE			
00612	5600	JMP I ENTER			
00613	0000	EDATE, C			
00614	4776	JMS PRINT			
00615	7773	-5			
00616	C304	D			
00617	C301	A			
00620	C324	T			
00621	C305	E			
00622	0240	SPACE			
00623	5613	JMP I DDATL			
00624	0000	CALGRP, C			
00625	4776	JMS PRINT			
00626	7765	-13			
00627	C303	C			
00630	C301	A			
00631	C314	L			
00632	C256	PRD			
00633	C307	G			
00634	C322	X			
00635	C320	P			
00636	C256	PRD			
00637	C316	N			
00640	C317	D			
00641	0240	SPACE			
00642	5624	JMP I CALGRP			
00643	0000	RTIME, C			
00644	4776	JMS PRINT			
00645	7763	-15			

00646	0322	R
00647	0325	U
00650	0315	N
00651	0240	SPACE
00652	0304	D
00653	0325	U
00654	0322	R
00655	0301	A
00656	0324	I
00657	0311	I
00660	0317	U
00661	0316	N
00662	0240	SPACE
00663	5643	JMP I RNTIME
00664	0000	STARIM, C
00665	4776	JMS PRINT
00666	7765	-13
00667	0323	S
00670	0324	I
00671	0301	A
00672	0322	R
00673	0324	I
00674	0240	SPACE
00675	0324	I
00676	0311	I
00677	0315	M
00700	0305	E
00701	0240	SPACE
00702	5664	JMP I STARIM
00703	0000	I0115, C
00704	4776	JMS PRINT
00705	7767	-11
00706	0316	N
00707	0317	U
00710	0256	PRD
00711	0240	SPACE
00712	0302	U
00713	0311	I
00714	0324	I

00715	0323	S
00716	0240	SPACE
00717	5703	JMP I IBITS
00720	0000	COMNIS, O
00721	4776	JMS PRINT
00722	7770	-10
00723	0303	C
00724	0317	D
00725	0315	M
00726	0315	N
00727	0305	E
00730	0316	N
00731	0324	I
00732	0323	S
00733	4777	JMS GRF
00734	5720	JMP I COMNIS
00735	0000	PRNIGO, C
00736	4777	JMS GRF
00737	4776	JMS PRINT
00740	7773	-5
00741	0322	N
00742	0305	C
00743	0301	A
00744	0304	D
00745	0331	Y
00746	5735	JMP I PRNIGO
00747	0000	TIMNOW, O
00750	4776	JMS PRINT
00751	7773	-5
00752	0324	I
00753	0311	I
00754	0315	M
00755	0305	E
00756	0240	SPACE
00757	5747	JMP I TIMNOW
00760	0000	CATAID, O
00761	4776	JMS PRINT
00762	7766	-12
00763	0304	D

00764	0301	A
00765	0324	I
00766	0301	A
00767	0240	SPACE
00770	0324	I
00771	0331	Y
00772	0320	P
00773	0305	F
00774	0240	SPACE
00775	5760	JMP I DATAID

/

00776	1000
-------	------

00777	1020
-------	------

*1000

/

/ ROUTINE TO PRINT ALPHANUMERIC CHARACTERS ON THE JTY

01000	0000	PRINT, C
01001	1600	IAD I PRINT
01002	3003	CCA IXI
01003	2203	ISZ PRINT
01004	1600	GCPRNT, IAD I PRINT
01005	4212	JMS TYPE
01006	2200	ISZ PRINT
01007	2003	ISZ IXI
01010	5204	JMP GCPRNT
01011	5600	JMP I PRINT

/ ROUTINE TO TYPE ONE ASCII CHARACTER

01012	0000	TYPE, C
01013	6041	ISF
01014	5213	JMP .-1
01015	5046	TLS
01016	7300	CLA CLL
01017	5612	JMP I TYPE

/

01020	0000	GRLF, C
01021	1227	IAD K215
01022	4212	JMS TYPE
01023	1226	IAD K212
01024	4212	JMS TYPE

01025 5620 JMP I GR1F

01026 5212 K212, 212

01027 5215 K215, 215

01030 5000 INI11, C

01031 7300 CLA CLL

01032 6002 IOF

01033 6046 FLS

01034 6032 KCC

01035 1077 IAD K17

01036 3011 DCA 11

01037 5630 JMP I INI11

/ ROUTINE TO WRITE OUT TAG DATA

01040 5000 INI12, C

01041 1112 IAD M12

01042 3003 DCA IX1

01043 1077 IAD K17

01044 3010 DCA 10

01045 1036 IAD RUF1

01046 3011 DCA 11

01047 1410 IAD I 10

01050 3411 DCA I 11

01051 2003 ISZ IX1

01052 5247 JMP .-3

/ INCREMENT NCALS AND STARTIN, AND CHANGE THEIR SIGNS

01053 1027 IAD SIR1M

01054 7040 CMA

01055 3027 DCA SIR1M

01056 1026 RESTART, IAD NCALS

01057 7040 CMA

01060 3020 DCA NCALS

01061 1104 IAD M1

01062 3070 DCA BRNCH1

01063 1104 IAD M1

01064 3071 DCA BRNCH2

01065 1104 IAD M1

01066 3073 DCA SECNDS

01067 3033 DCA NRECS

/ 10 NUMBERS TO BE TRANSFERRED

/GET A NUMBER

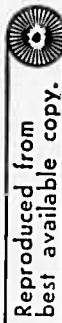
/TRANSFER IT

/DONE.....

/NO. GO BACK FOR MORE.

/REENTER HERE AFTER ERDOUT ROUTINE.

01070	3034	DCA SRATHI
01071	3035	DCA SRATIO
01072	3072	DCA CALND
01073	3442	DCA I RECN01
01074	3447	DCA I RECN02
01075	1355	TAD TICSKP
01076	3350	DCA TOCJMP
01077	1302	TAD TICKER
01100	3347	DCA TICJMP
01101	5640	JMP I INITL2 /DONE.
01102	5351	TICKER, 5351
/		



/		ROUTINE TO DETECT ONE-SECOND TICKS
/		
01103	6030	TICTOC, C
01104	3324	DCA NCTIK
01105	1076	TAD K3
01106	6542	ADSC /ONE-SECOND TICKS ARE ON CHANNEL THREE
01107	4357	JMS LAG17
01110	6532	TIC, ADCV
01111	4365	JMS LAG9
01112	6534	ADRP
01113	7500	SMA
01114	5317	JMP ICC /A POSITIVE VALUE WAS DETECTED
01115	3324	DCA NCTIK /DEPOSIT NEGATIVE SAMPLES IN NOTIK
01116	5310	JMP TIC /GO BACK AND LOOK FOR A POSITIVE SAMPLE.
01117	7200	IOC, CLA
01120	1324	TAD NCTIK
01121	7700	SMA CLA /A NEW TICK WAS DETECTED IF THE
/		/PREVIOUS SAMPLE WAS NEGATIVE.
01122	5310	JMP TIC /IF NOT, SAMPLE AGAIN.
01123	5703	JMP I TICTOC
01124	6060	NOTIK, C
/		
/		
/		ROUTINE TO MEASURE THE SAMPLING RATE
/		
01125	6060	SAMPRT, C
01126	6541	SRTI, ADCC /STROPS ARE ON CHANNEL ZERO.

01127	4357	JMS LAG17	/DELAY 17 USEC FOR THE MUX TO SETTLE.
01130	6532	ADCV	/SAMPLE THE STROBE DATA.
01131	4365	JMS LAG9	/DELAY 9 USEC TO ALLOW TIME FOR A/D CONVERSION.
01132	6534	ADRB	
01133	7710	SPA CLA	/SKIP IF A STROBE WAS DETECTED.
01134	5330	JMP *-4	
01135	1076	TAD K3	/PREPARE TO SAMPLE ONE-SECOND TICKS ON CH 3.
01136	6542	ADSC	
01137	2035	ISZ SRATLO	/BUMP THE LOW-ORDER SAMPLING RATE COUNT.
01140	5142	JMP *-2	
01141	2034	ISZ SRATFI	
01142	4357	JMS LAG17	/BUMP THE HIGH-ORDER SAMPLING RATE COUNT.
01143	6532	ADCV	/DELAY 17 USEC FOR MUX TO SETTLE.
01144	4365	JMS LAG9	/SAMPLE CHANNEL 3.
01145	6534	ADRB	
01146	7710	SPA CLA	
01147	5351	TICJMP, JMP *-2	/SKIP IF TICK LEVEL IS STILL POSITIVE.
01150	5326	TCCJMP, JMP SRT1	/TICK LEVEL IS NEGATIVE.
01151	1350	TAD TCCJMP	
01152	3347	DCA TICJMP	/NOW, TO END SAMP RATE COUNT AT THE NEXT TICK,
01153	1356	TAD TCCSKP	/CHANGE TICJMP TO JMP SRT1
01154	3350	DCA TCCJMP	/AND
01155	5326	TICSKP, JMP SRT1	/CHANGE TCCJMP TO JMP I SAMPRT
01156	5725	TCCSKP, JMP I SAMPRT	

/ /
/ /
/ /
/ /

DELAY ROUTINES TO ALLOW TIME FOR SETTLING OF THE MUX
AND COMPLETION OF THE A-D CONVERSION OF THE DATA SAMPLES.

01157	0000	LAG17, 0
01160	7300	CLA CLL
01161	7415	ASR
01162	0000	0
01163	1357	TAD LAG17
01164	5370	JMP LAGOUT
01165	0000	LAG9, 0
01166	7200	CLA
01167	1365	TAD LAG9
01170	3372	LAGOUT, DCA LAGRTN

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```

01171 5772      JMP I LAGRIN
01172 0000      LAGRIN, 0
/

```

```

*1200
/

```

```

/ ROUTINE TO DELAY 200 MILLISECUNDS
/

```

```

01200 0000      ENDLAG, 0
01201 1114      TAD M14
01202 3003      DCA IX1
01203 1043      ENLOOP, TAD BUFR2
01204 3010      DCA IX1
01205 1120      TAD M3124
01206 3004      DCA IX2
01207 3410      DCA I 10
01210 2004      ISZ IX2
01211 5207      JMP *-2
01212 2003      ISZ IX1
01213 5203      JMP ENLOOP
01214 5600      JMP I ENDLAG
/

```

```

/THIS LOOP CLEARS
/THE SAMPLE STORAGE AREA
/IN BUFFER 2.

```

```

/ CALCULATION OF THE NUMBER OF RECORDS IN THE RUN
/

```

```

01215 0000      RECCNT, 0
01216 1075      TAD K2
01217 6542      ADSC
01220 7200      CLA
01221 1030      TAD RUNTIM
01222 3225      DCA MPV1
01223 1035      TAD SRATLO
01224 7425      MCL MOV
01225 0000      MPV1, 0
01226 3006      DCA TEMPI
01227 7701      CLA MCA
01230 3007      DCA TEMP2
01231 1030      TAD RUNTIM
01232 3235      DCA MPV2
01233 1034      TAD SRATHI

```

```

/TO COMPUTE THE NO. OF RECORDS (NRECS),
/THE RUNTIME (IN MINUTES) IS
/MULTIPLIED BY THE SAMPLING RATE
/(IN SAMPLES-PER-SECOND) AND DIVIDED
/BY ONE-SIXTIETH OF THE NUMBER OF
/SAMPLES PER RECORD (1620/60 = 27).

```

01234	7425	MCL MUY	
01235	0000	MPV2,	
01236	7701	CLA MCA	
01247	1000	TAD TEMPI	
01240	3006	DCA TEMPI	
01241	1006	TAD TEMPI	
01242	7040	CMA	TEST THE HIGH-ORDER PRODUCT OF SRATE
01243	1102	TAD K33	AND RUNTIM. IT MUST BE SMALLER THAN
01244	7710	SPA CLA	THE DIVISOR, 27, FOR DIVISION TO
01245	5306	JMP EROU11	TAKE PLACE.
01246	1102	TAD K33	DECIMAL 27.
01247	3255	DCA CIV1	
01250	3003	DCA IX1	CLEAR IX1.
01251	1007	TAD TEMPI2	
01252	7421	MCL	
01253	1006	TAD TEMPI	
01254	7407	CVI	DIVIDE THE PRODUCT OF SRATE AND RUNTIM BY 27.
01255	0000	EIV1,	
01256	7104	CLL RAL	TEST TO SEE IF THE REMAINDER IS
01257	7041	CIA	LARGER THAN HALF THE DIVISOR.
01260	1102	TAD K33	
01261	7710	SPA CLA	IT ISNT.
01262	2003	ISZ IX1	IT IS. PUT A 1 IN IX1.
01263	7501	MCA	
01264	1003	TAD IX1	
01265	3033	DCA ARECS	
/			
/		STORE SAMPLING RATE AND NUMBER OF RECORDS IN THE RUN	
/		IN THE CUIPUT BUFFERS	
01266	1034	TAD SRATH1	
01267	3037	DCA SRATH1	
01270	1034	TAD SRATH1	
01271	3044	DCA SRATH2	
01272	1035	TAD SPATLO	
01273	3040	DCA SRTLPI	
01274	1035	TAD SRATLO	
01275	3045	DCA SRTL92	
01276	1033	TAD ARECS	

01277	3441	DCA I NRCSB1
01300	1033	IAD NRECS
01301	3446	DCA I NRCSB2
01302	1033	IAD NRECS
01303	7041	CIA
01304	3033	DCA ARECS
01305	5615	JMP I RECONI
/		
/		
/		
/		
ERROR ROUTINES IN CASE THE SELECTED RUN DURATION IS TOO LONG.		
01306	0000	EROU11, C
01307	4777	JMS MAGIS
01310	0415	C415
01311	4770	JMS MAXTIM
01312	4767	JMS BCDHIN
01313	4325	JMS ERRMSG
01314	4776	JMS ENTER
01315	4775	JMS RNTIME
01316	1101	IAD K27
01317	3011	DCA 11
01320	4774	JMS NUMBER
01321	7777	-1
01322	1451	IAD I CALPFI
01323	3026	DCA NCALS
01324	5773	JMP RESRT
/		/START OVER.
/		
/		
/		
ROUTINE TO PRINT THE ERROR MESSAGE		
01325	0000	ERRMSG, 0
01326	4772	JMS CRLF
01327	4772	JMS CRLF
01330	4354	JMS MAX
01331	4775	JMS RNTIME
01332	4354	JMS ISZTZ
01333	5725	JMP I ERRMSG
01334	0000	MAX, 0
01335	4771	JMS PRINT
01336	7764	-14

01337	0324	I
01340	0310	n
01341	0305	E
01342	0240	SPACE
01343	0315	M
01344	0301	A
01345	0330	X
01346	0311	I
01347	0315	M
01350	0325	U
01351	0315	M
01352	0240	SPACE
01353	5734	JMP I MAX
01354	0000	1S2222, 0
01355	4771	JMS PRINT
01356	7771	-7
01357	0311	I
01360	0323	S
01361	0240	SPACE
01362	0000	DEC3, 0
01363	0000	DEC4, 0
01364	0000	DEC1, 0
01365	0000	DEC0, 0
01366	5754	JMP I 1S2227
01367	1430	
01370	1400	
01371	1000	
01372	1020	
01373	1056	
01374	0464	
01375	0643	
01376	0600	
01377	0400	
*1400		

/ ROUTINE TO COMPUTE THE MAXIMUM RUN DURATION.

01400	0000	MAXIM, 0	
01401	7201	CLA IAC	
01402	3225	DCA CIVIC2	/STORE 1 IN DIVID2
01403	1035	TAD SRATLO	/PREPARE TO SCALE THE SAMPLING RATE UNTIL
01404	7421	MQL	/IT IS A 12-BIT NUMBER OR SMALLER.
01405	1034	TAD SRATHI	
01406	7450	TEST, SNA	/IS SAMPLING RATE LESS THAN 4096....
01407	5214	JMP COMPI	/YES.
01410	7417	LSR	/NO. DIVIDE THE RATE BY 2.
01411	0000	0	
01412	2225	ISZ CIVIC2	/INCREMENT THE SCALE DIVIDER.
01413	5206	JMP TEST	/REPEAT THE TEST.
01414	7701	COMPI, CLA MCA	
01415	3222	DCA CIVIC1	/STORE THE SCALED SAMPLING RATE IN DIVID1.
01416	7040	CMA	/MULTIPLY THE MAXIMUM NO. OF
01417	7425	MQL MUY	/RECORDS (4095) BY 27.
01420	0033	33	
01421	7407	DVI	/AND DIVIDE BY THE SCALED
01422	0000	DIVID1, 0	/SAMPLING RATE.
01423	7200	CLA	
01424	7407	DVI	/NOW DIVIDE BY THE SCALE
01425	0000	CIVID2, 0	/DIVIDER.
01426	7200	CLA	/HOLD THE COMPUTED MAXIMUM RUN TIME.
01427	5600	JMP I MAXIM	

/ ROUTINE TO CONVERT OCTAL TO BINARY NUMBERS AND FORMAT FOR BCD PRINTOUT.

01430	0000	BCDIN, 0	
01431	7407	DVI	
01432	1750	1750	
01433	3006	DCA TEMPI	
01434	7501	MCA	
01435	1103	TAD K260	
01436	3681	DCA I DECIM3	
01437	1006	TAD TEMPI	

01440	7421	NGL
01441	7427	DVI
01442	C144	144
01443	3036	DCA TEMP1
01444	7501	NQA
01445	1103	IAD K260
01446	3632	DCA 1 DECIM2
01447	1006	IAD TEMP1
01450	7421	NGL
01451	7427	DVI
01452	C012	12
01453	1103	IAD K260
01454	3664	DCA 1 DECIM0
01455	7501	NQA
01456	1103	IAD K260
01457	3663	DCA 1 DECIM1
01460	5630	JMP 1 BCDHIN
/		
01461	1362	DECIM3, DEC3
01462	1363	DECIM2, DEC2
01463	1364	DECIM1, DEC1
01464	1365	DECIM0, DEC0
/		

8.0 APPENDIX 3

LISTING OF PROGRAM
FOR SAMPLING AND RECORDING MIF DATA

MAINLINE ROUTINE

01200	1033	GETCIA, TAD BUF1	
01201	4211	JMS SAMPLE	
01202	1033	TAD BUF1	
01203	4132	JMS BUFOUT	/WRITE OUT BUFFER 1
01204	1037	TAD BUF2	
01205	4211	JMS SAMPLE	
01206	1037	TAD BUF2	
01207	4132	JMS BUFOUT	/WRITE OUT BUFFER 2.
01210	5200	JMP GETCIA	
01211	3000	SAMPLE, C	
01212	3010	DCA IO	/STORE THE BUFFER ORIGIN
01213	1010	TAD IO	
01214	1126	TAD SYNCY	
01215	3011	DCA II	/COMPUTE AND STORE THE ORIGIN OF
01216	3122	DCA SAMPNO	/THE SYNC-SAMPLE LOCATION ARRAY.
01217	1113	TAD ACSYNG	/CLEAR THE SAMPLE COUNTER.
01220	3125	DCA SYNCNO	/= MAX. NO. OF SYNC-PULSES PER BUFFER.
01221	1112	TAD NCPEAK	
01222	3117	DCA PEAKNO	/= -MAX NO. OF PEAKS PER BUFFER = -800.
01223	2070	ISZ EXITST	/ = 0 FOR NORMAL EXIT FROM PRECEDING BUFFER.
01224	5264	JMP LCOB	
01225	4777	JMS MTFST	/RESYNCHRONIZE. START AT THE NEXT MTF SYNC PULSE.
01226	3120	DCA SAMPL1	
01227	3131	DCA ZROSLP	/CLEAR THE EQUAL-AMP. SAMPLE COUNTER.
01230	3127	DCA UPSLP	/CLEAR THE SLOPE INDICATOR.
01231	5264	JMP LCOB	
01232	6532	MTFSPL, ADCV	/SAMPLE THE MTF DATA.
01233	2122	ISZ SAMPAC	/INCREMENT THE SAMPLE COUNT
01234	1007	TAD TEMP2	/FETCH THE SYNC-PULSE SAMPLE.
01235	7500	SMA	/SKIP ON NO SYNC-PULSE.
01236	5347	JMP SPTEST	
01237	3115	DCA ACSYAC	/STORE THE NEGATIVE SYNC-PULSE SAMPLE.
01240	1120	TAD SAMPL1	/SHIFT THE PREVIOUS SAMPLE
01241	3121	DCA SAMPL2	/DOWN ONE LEVEL.
01242	6534	ADRB	/READ THE NEW DATA SAMPLE.
01243	6544	ADIC	/ (MUX = 1)
01244	3120	DCA SAMPL1	/STORE IT.

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01245	1121	TAD SAMPL2	/FETCH THE PREVIOUS SAMPLE.
01246	7041	CIA	/CHANGE ITS SIGN
01247	1120	TAD SAMPL1	/AND ADD THE NEW SAMPLE.
01250	7510	SPA	/SKIP IF THE SLOPE IS ZERO OR POSITIVE
01251	5271	JMP DOWN	/TEST FOR A POSSIBLE PEAK.
01252	7640	SZ4 CLA	/SKIP ON ZERO SLOPE.
01253	5256	JMP UP	
01254	2131	IS7 ZROSLP	/INCREMENT THE COUNTER OF EQUAL-AMPL. SAMPLES.
01255	5341	JMP LAG4PS	/DELAY 4.5 USEC AND RETURN TO SPSPL1.
01256	3131	DCA ZROSLP	/CLEAR THE ZERO SLOPE COUNTER.
01257	7001	IAC	/SET THE UPSLOPE INDICATOR TO 1.
01260	3127	DCA UPSLP	/
01261	6532	SPSPL1, ADCV	/SAMPLE THE MIF SYNC-PULSE LINE.
01262	4334	JMS DELAY	/IDLE 10 USEC.
01263	6534	ADRB	/READ THE SYNC-PULSE SAMPLE.
01264	6541	ADCC	/IMUX = 0)
01265	3007	DCA TEMP2	/TEMPORARILY STORE THE SYNC-PULSE SAMPLE.
01266	7001	IAC	
01267	4334	JMS DELAY	/IDLE 10.5 USEC.
01270	5232	JMP MTFSP	/GO BACK TO SAMPLE THE MIF DATA.
/			
01271	1127	DOWN, TAD UPSLP	/FETCH THE UPSLOPE INDICATOR.
01272	7650	SVA CLA	/A PEAK IS HERE IF A PRECEDING SLOPE WAS POS.
01273	5342	JMP LAG3PO	/END PEAK HERE. WE ARE ON A DOWNSLOPE.)
01274	1131	TAD ZROSLP	/THE LOCATION OF THE PEAK IS THE CURRENT
01275	7041	CIA	/SAMPLE NO., MINUS 1/2 THE COUNT OF THE
01276	6532	SPSPL2, ADCV	/SAMPLE THE SYNC-PULSE LINE)
01277	7415	ASR	/SUCCESSIVE EQUAL-AMPLITUDE SAMPLES.
01300	0000	0	/
01301	1122	TAD SAMPNC	/
01302	3410	DCA I 10	/STORE THE PEAK LOC'N. IN THE NEXT BUFFER SLOT.
01303	6534	ADRB	/READ THE SYNC-PULSE SAMPLE.
01304	6541	ADCC	/IMUX = 0)
01305	3007	DCA TEMP2	/AND STORE IT TEMPORARILY.
01306	1121	TAD SAMP2	/STORE THE AMPLITUDE OF THE PEAK IN THE
01307	3410	DCA I 10	/NEXT AVAILABLE BUFFER SLOT.
01310	3131	DCA ZROSLP	/CLEAR THE EQUAL-AMPLITUDE SAMPLE COUNTER.
01311	3127	DCA UPSLP	/CLEAR THE UPSLOPE INDICATOR.
01312	2117	IS2 PFAKNO	/INCREMENT THE PEAK NUMBER COUNTER.
01313	5232	JMP MTFSP	/GO BACK TO SAMPLE THE MIF DATA.

```

/
/
01314 2113 /THE BUFFER IS FULL.
01315 5320 /DECREMENT THE MAXIMUM JUMPER OF SYNC PULSES.
01316 1107 JPB .+3
01317 7402 /SOME THING IS WRONG. THE NUMBER OF
/ SYNC-PULSES IS DOWN TO ZERO.
01320 3070 /
01321 1011 /INDICATE THE KIND OF EXIT.
01322 3003 /FETCH THE ADDRESS OF THE FINAL PEAK NUMBER.
01323 1403 DCA IX1
01324 3434 /
01325 1403 /FETCH THE FINAL PEAK NUMBER,
01326 3440 /AND STORE IT
01327 1074 /IN BOTH BUFFERS.
01330 6542 /
01331 2436 /SET PUY = 2 TO SAMPLE THE DATA CONDITION.
01332 2442 /
01333 5611 /
/
/
/

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/**DELAY ROUTINES**

```

01334 0000 DELAY, 0
01335 3337 DCA LAGT
01336 7415 ASR
01337 0000 LAGT, 0
01340 5734 JNP I DELAY
/
01341 7200 LAG4PO, CLA
01342 7200 LAG3PO, CLA
01343 5261 JNP SPSPL1
/
/
01344 0000 LAG17, 0
01345 4334 JMS DELAY
01346 5744 JNP I LAG17
/

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		SPTST, CLA		
01347	7200			
01350	1115	TAD NOSYNC		
01351	7700	SMA CLA		/A SYNC-PULSE IS HERE IF LAST S-P WAS NEGATIVE.
01352	5240	JMP RTN1		/NO SYNC PULSE HERE. RETURN TO THE MAINLINE.
01353	3115	DCA NOSYNC		/A SYNC-PULSE IS HERE. CLEAR NOSYNC.
01354	2125	ISZ SYNCNO		/INCREMENT THE COUNTER OF SYNC PULSES.
01355	5357	JMP +2		/SKIP IF NOT THE LAST SYNC-PULSE.
01356	5320	JMP EXIT		/SYNCNO=0. PERFORM A NORMAL EXIT.
01357	1117	TAD PEAKNO		/FETCH THE CURRENT PEAK NUMBER.
01360	7041	CIA		/CHANGE ITS SIGN.
01361	3411	DCA I 11		/AND STORE IT IN THE BUFFER.
01362	5240	JMP RTN1		/RETURN TO THE MAINLINE ROUTINE.
01377	0341			